

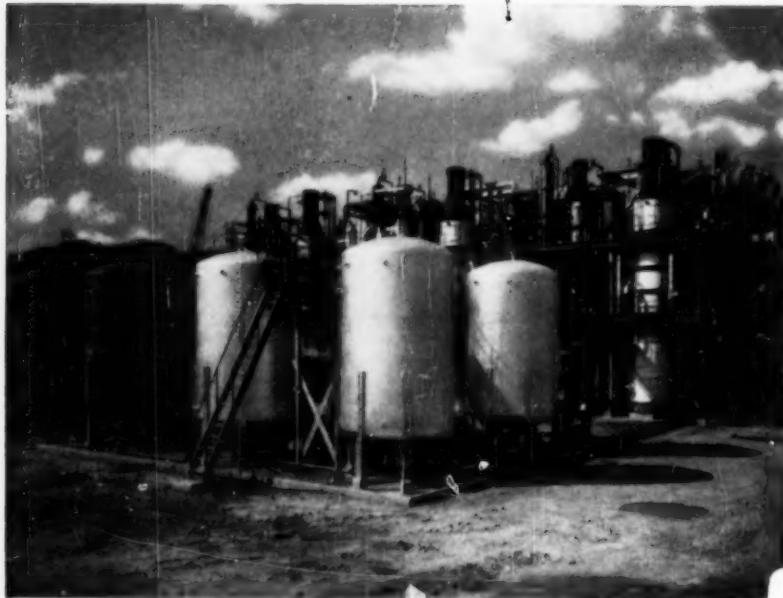
JANUARY 1953

# Chemical Engineering Progress

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

# for **ETHYLENE OXIDE**

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## CARBIDE AND CARBON CHEMICALS COMPANY

A Division of  
Union Carbide and Carbon Corporation  
30 East 42nd Street UCC New York 17, N.Y.



Volume 49  
Number 1

# Chemical Engineering Progress

JANUARY  
1953

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SPECIAL flow control enables the Bar-Nun Rotary Sifter to give a fast, clean, complete separation on every sieve. Additional sieves make different separations, or double or triple the capacity of the single sieve. Result: Surprisingly big capacity in very little floor space. Even a crowded plant layout can usually accommodate the Bar-Nun, because flexibility of flow permits a wide choice of outlet locations.

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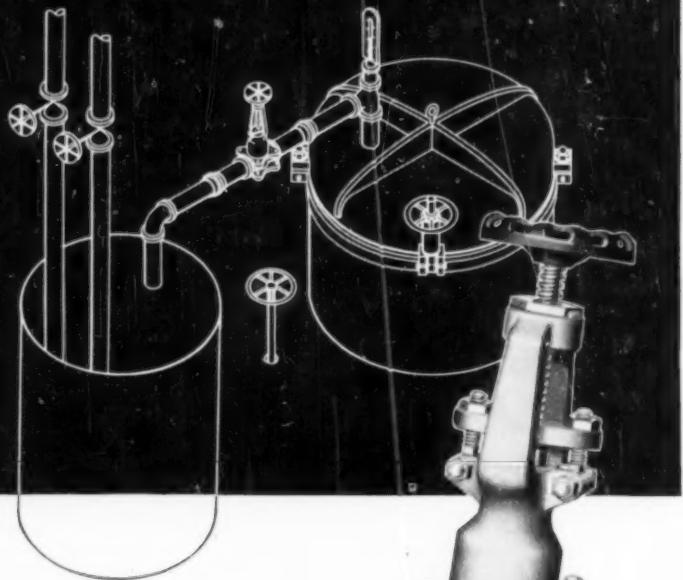


1311 SOUTH CICERO AVE.  
CHICAGO 50, ILLINOIS

# *It's not what you Pay for Valves ... it's what they Cost you*

*on Corrosive  
Solutions  
for example*

*(A Case History)*

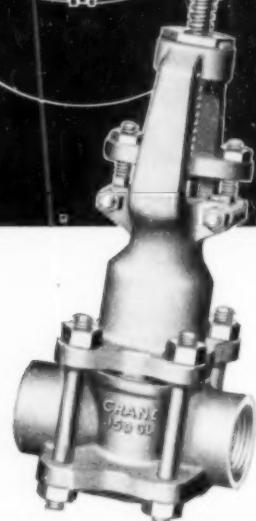


What you pay for valves is not the final criterion of value. Not when maintenance costs can quickly equal or exceed purchase price. And a valve that hinders production is no bargain at any price—no attraction to a thrifty buyer.

Take the case of Phoenix Dye Works in Chicago. Valves in acid dye lines on package dye machines were constantly sticking and leaking. Maintenance cost was excessive; production schedules lagged. Many types of valves and cocks were tried, but none lasted more than 2 months.

The problem was solved by installing Crane 18-8 Mo Plug Gate Valves. With more than 3 years' satisfactory service received, the user reports on these valves: No leakage . . . no maintenance expense . . . no sign of corrosion . . . operate like new.

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Crane Plug Gate in all 18-8 Mo or Monel, in the big Crane line of corrosion-resistant piping materials.



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**VALVES • FITTINGS • PIPE • PLUMBING • HEATING**

**STRUTHERS WELLS**

# FIRED HEATING EQUIPMENT

for Dowtherm  
and Other Fluids

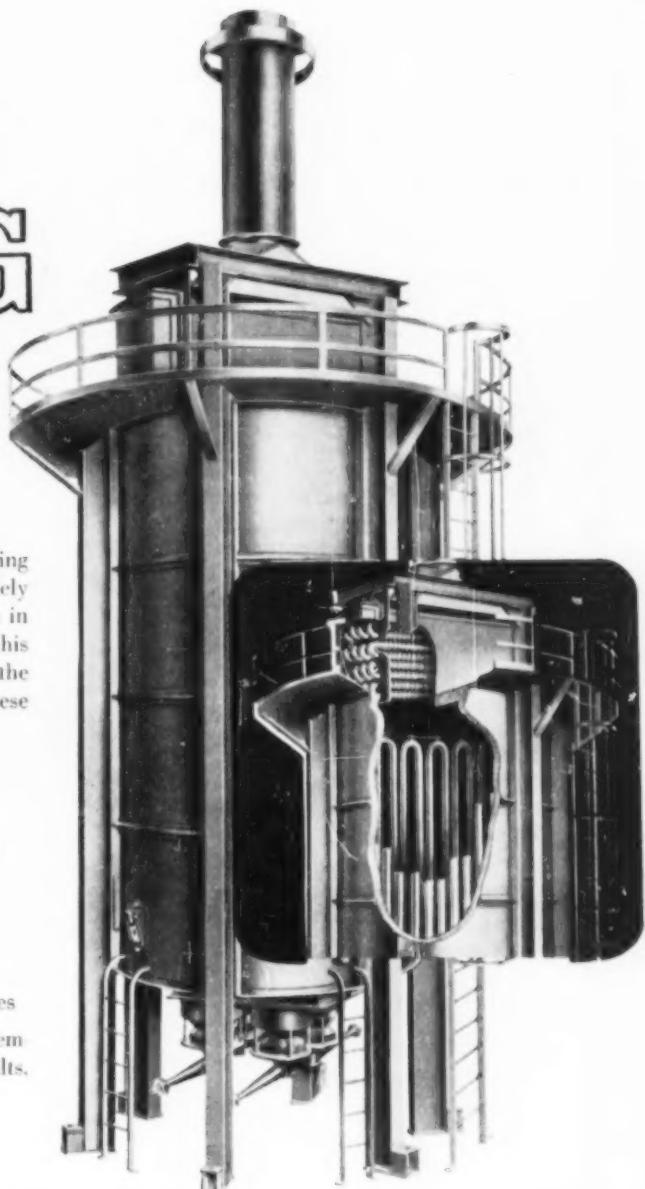
The Struthers Wells forced circulation system utilizing Dowtherm as a heat transfer medium has been widely accepted by the chemical industry and other users in recent years. Scores of large installations in this country, and numerous units abroad, testify to the universal satisfaction of the user. Many of these installations are repeat orders.

This system offers the user:

- Proven performance at maximum temperatures
- Trouble-free operation, no coking or overheating of equipment
- High thermal efficiencies
- Close temperature control
- Complete equipment and engineering service
- Moderate initial cost and low maintenance charges

We also supply equipment for heating gases to high temperatures—for superheating steam—heating asphalts, absorption oil and a wide range of services.

Good deliveries are available in standard sizes.



### *Typical Installations*



Write for Bulletin B-45  
on your letterhead,  
please



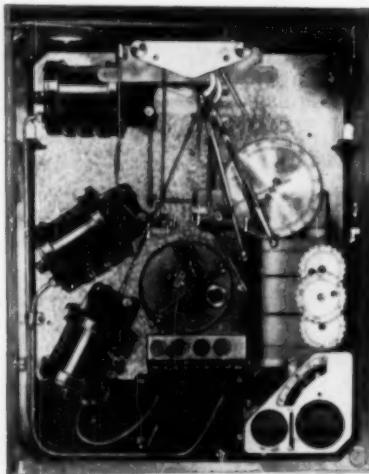
**STRUTHERS WELLS CORPORATION**  
**WARREN, PA.**

Plants at Warren, Pa. • Titusville, Pa.

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# NEW FISCHER & PORTER automatic FLOW RATIO CONTROLLER

Compact size with extreme precision of ratio control are important advances in this new Fischer & Porter Ratio Controller. Designed specifically for flow ratio control, it makes a perfect combination teamed with the new P-4 Pneumatrol and highly accurate Flowrator meters or variable area cell kinetic manometers, to assure accurate and dependable ratio control of fluids, gases or slurries. Receives pneumatic, electrical, or electronic primary signals. Review the features below, then mail the handy coupon for complete engineering and application data.

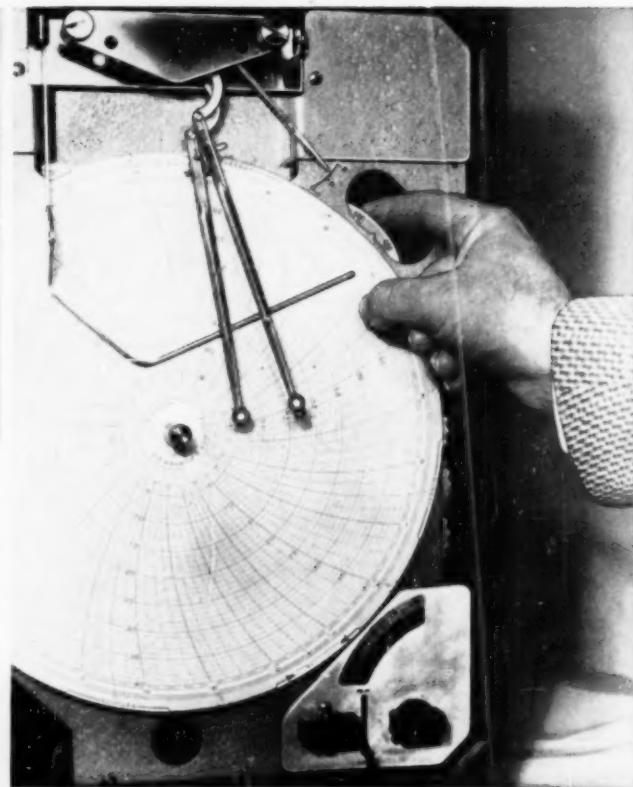


Interior view of standard Ratio Controller with pneumatic set ratio adjustment.

## CHECK THESE FEATURES:

- Extreme flexibility
- Wide range of ratio
- Based on linear scale primaries
- Control deviation indicator
- Primary element fully corrosion resistant
- Highly visible ratio setting dial
- Extremely compact stack mounting

© 1952



The compact stack mounting of the new Ratio Controller atop the P-4 Pneumatrol provides the simplest possible unit. The large (10½" scale) ratio setting dial permits precise ratio settings which are visible through the door. F & P wide range, linear scale primaries give extreme range of ratio (6:1 to 1:1 to 1:6; a total of 36:1).



## FISCHER & PORTER COMPANY 110 COUNTY LINE ROAD, HATBORO, PENNA.

Please send me by return mail complete information on your new Ratio Controller.

NAME \_\_\_\_\_ POSITION \_\_\_\_\_

COMPANY \_\_\_\_\_

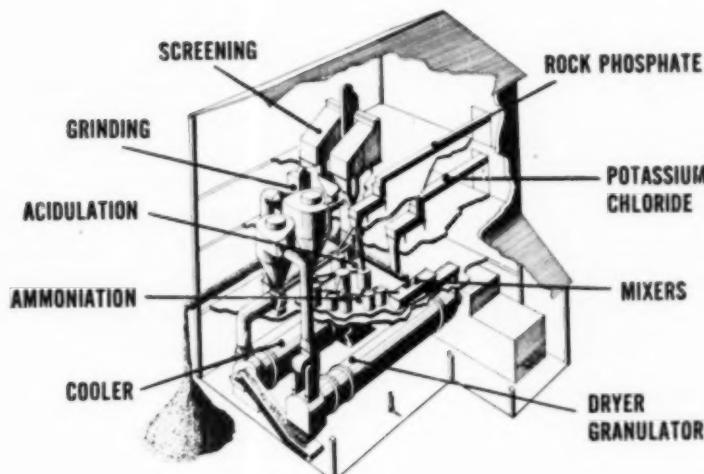
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# VII advantages

of the ST-GOAIN Process for  
the Manufacture of Complete  
Nitrophosphate Fertilizers

- 1** The St-Gobain process manufactures granulated fertilizers in one continuous automatic operation. The same equipment can be used to produce various N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O formulae.
- 2** Can produce end product in any sized granules desired.
- 3** St-Gobain plants are available in capacities of 30,000 tons of produced nitro-phosphates per year and up.
- 4** You benefit from improvements and experience of many years of successful operation on a large industrial scale.
- 5** St-Gobain process, with the same equipment, permits the use of either sulphuric or phosphoric acid according to the formula of the required fertilizer.
- 6** Capital investment is low due to the use of simple equipment.
- 7** Operating costs are low due to a continuous automatic operation and high yields.



For complete information write, wire or phone:

*General*  
INDUSTRIAL  
DEVELOPMENT  
CORPORATION

270 PARK AVENUE, NEW YORK 17, N.Y.

Examples of Formulae Produced by  
St-Gobain Process

N%	P.O.%	K.O%	
10	10	17	(sulfo-nitric acidulation)
11	11	11	" " "
10	15	20	(phospho-nitric acidulation)
12	15	18	" " "
12	12	20	" " "
14	14	14	" " "
10	20	20	" " "



AGENTS FOR ST-GOBAIN PROCESS

**THESE TWO EXAMPLES SHOW YOU**

# What Nordstrom Means by "Lubricant"



Nordstrom three-way Transflo valves on relief service at top of propylene tower separating propylene from propane.

## TYPICAL NORDSTROM REFINERY APPLICATIONS

Catalytic Polymerization	Thermal Cracking
Crude Topping and Vacuum Distillation	Phenol Extraction
Fluid Catalytic Cracking and Gas Recovery	Propane Deasphalting
Distillate Recovery in Cycling Plants	Cycloversion
Duo-Sol Solvent Extraction	Delayed Coking
Houdriflow Catalytic Cracking and Gas Recovery	Girbotol Process
Light Ends Fractionating	Propane Dewaxing
	Hydroforming Process
	Naphtha Polyforming
	Solexol Process
	Solvent Dewaxing
	Thermal Reforming

Nordstrom has compiled a series of specification sheets for each of these processes, showing recommended materials, pressure classes, lubricants and valve figure numbers. Ask your Nordstrom sales engineer to review them with you.

## TYPICAL NORDSTROM PROCESS INDUSTRY APPLICATIONS

Beverage Plants	Rubber Plants
Cement Plants	Sewage Plants
Chemical Plants	Smelters and Mines
Explosives	Soap Factories
Food Plants	Steel Mills
Gas Plants	Sugar Refineries
Ice and Refrigeration	Synthetic Ammonia
Paint and Lacquer	Synthetic Fibers
Paper and Pulp	Synthetic Plastics
Pharmaceuticals	Synthetic Rubber
Power and Steam Plants	Tanneries
	Textiles and Dyes
	Water Works

The new Nordstrom Corrosion-Resistant Valve Bulletin V-217 will make it easy for you to fit the right valve to each service. Write for a copy, Rockwell Manufacturing Company, Pittsburgh 8, Pa., or ask your Nordstrom sales engineer.

# -Sealed for POSITIVE SHUT-OFF"

Here are two typical Nordstrom valve process applications—one is a propylene tower, the other a dry hydrogen line.

They illustrate an important point in specifying valves for process service . . . if really tight shut-off of hard-to-hold gases or fluids is important, no valve can do the job better than Nordstrom.

Why? Because Nordstrom is the original lubricated plug valve. Nordstrom is the valve with the extra seal of plastic lubricant around the valve ports to check seepage of even the lightest, most penetrating substances.

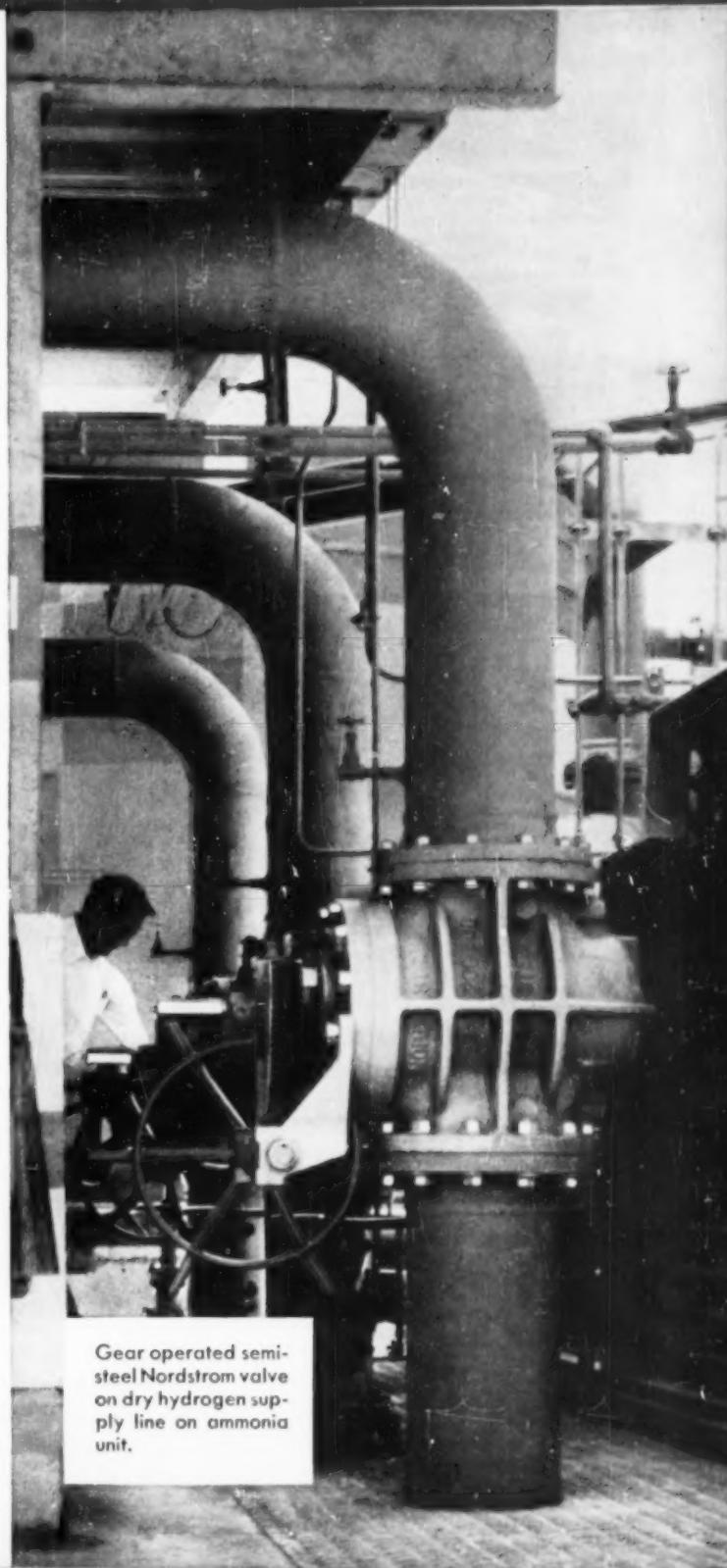
That, of course, means greater safety, and greater economy, too, because when leakage is prevented, valve life is far longer. And most important, it means uninterrupted operation of continuous process units—no down-time for avoidable valve repairs.

The same lubricant that seals, also keeps the valve ready to operate in an emergency.

Nordstrom valves are built in a wide range of sizes, pressures, special metals and body designs for the process industries, including three- and four-way designs for batching, blending and switching. Rockwell Manufacturing Company, Pittsburgh 8, Pa.

## ROCKWELL Built Nordstrom Valves *Lubricant-Sealed for Positive Shut-Off*

Another  Product



Gear operated semi-  
steel Nordstrom valve  
on dry hydrogen sup-  
ply line on ammonia  
unit.

# Centrifuge Chewing Gum?



...and one of the tougher problems that has been solved successfully by the Sharples Super Centrifuge.

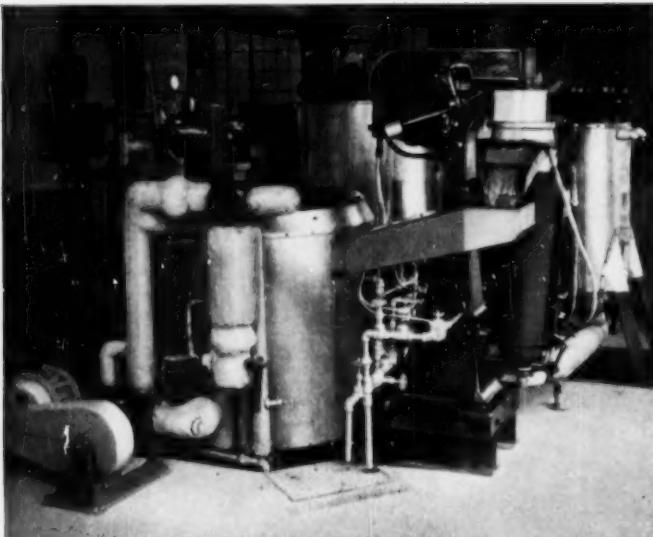
We mention the centrifugal clarification of molten chicle not only because of the highly viscous nature of chicle, and the cleanliness with which it must be processed—but for quite another reason:

A series of test runs made on a standard Sharples Super Centrifuge determined the design features necessary to handle this material that is difficult to transfer even through pipe lines. A new rotating element was engineered; new methods of introducing the chicle into this element were developed; radical changes in discharge covers were required; the frame was steam jacketed and special power requirements were detailed.

Solving the chicle problem represents the kind of centrifugal engineering for which the Sharples Corporation is well known and on which you can depend.

Added to the seven basic types of Sharples Centrifuges is the engineering ability and long experience of an organization skilled in the most effective application of one of these centrifuge types to your specific need.

Courtesy of American Chicle Company



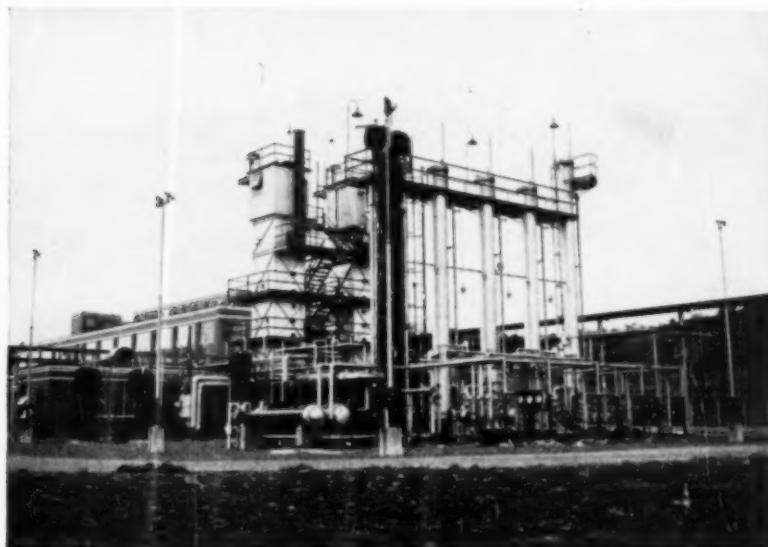
# SHARPLES



THE SHARPLES CORPORATION • 2300 WESTMORELAND STREET, PHILADELPHIA 40, PENNA.  
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# Girdler Process News



Girdler HYGIRTOL® Plant at U. S. Bureau of Mines Synthetic Liquid Fuels Plant . . . supplies both pure hydrogen and various mixtures of synthesis gas.

## Complete engineering-construction service assures a job "well done"

FOR PROCESS PLANTS in the chemical, natural gas, and petroleum industries, Girdler assumes unit responsibility for design, process engineering, and construction. This saves you engineering manhours and time. Most important, it assures proper co-ordination of the whole project and successful results.

Girdler has broad experience in handling complete "process packages" . . . covering design and construction of process plants involving very high operating pressures,

high temperature reactions, and corrosive substances.

For the first step in your planning, obtaining factual data for evaluation, Girdler offers cost-plus contracts covering preliminary engineering . . . process recommendations, flow diagrams, general equipment specifications, plot plans, cost estimates, and operating cost data. This simplifies planning, and assures sound decisions. For a job "well done", call on Girdler in the planning stages of your processing facilities.

\*HYGIRTOL is a trade mark of The Girdler Corp.

### The **GIRDLER** Corporation

LOUISVILLE 1, KENTUCKY  
Gas Processes Division

GAS PROCESSES DIVISION: Designers, Engineers, and Constructors for the Petroleum and Chemical Industries

VOTATOR DIVISION: Processing Apparatus for the Food and Chemical Industries

THERMEX DIVISION: Industrial High Frequency Dielectric Heating Apparatus



PROCESS RESEARCH—Girdler's research and development department is well equipped to assist with all types of process problems. A technical staff is available for consultation, and Girdler's research group can be employed on special problems at reasonable cost.



ENGINEERING—Experienced executives direct a group of engineering specialists, trained for every job requirement. In addition to basic process and equipment design, Girdler engineers have broad experience in buildings, foundations, electrical systems, boiler plants, instrumentation, etc.

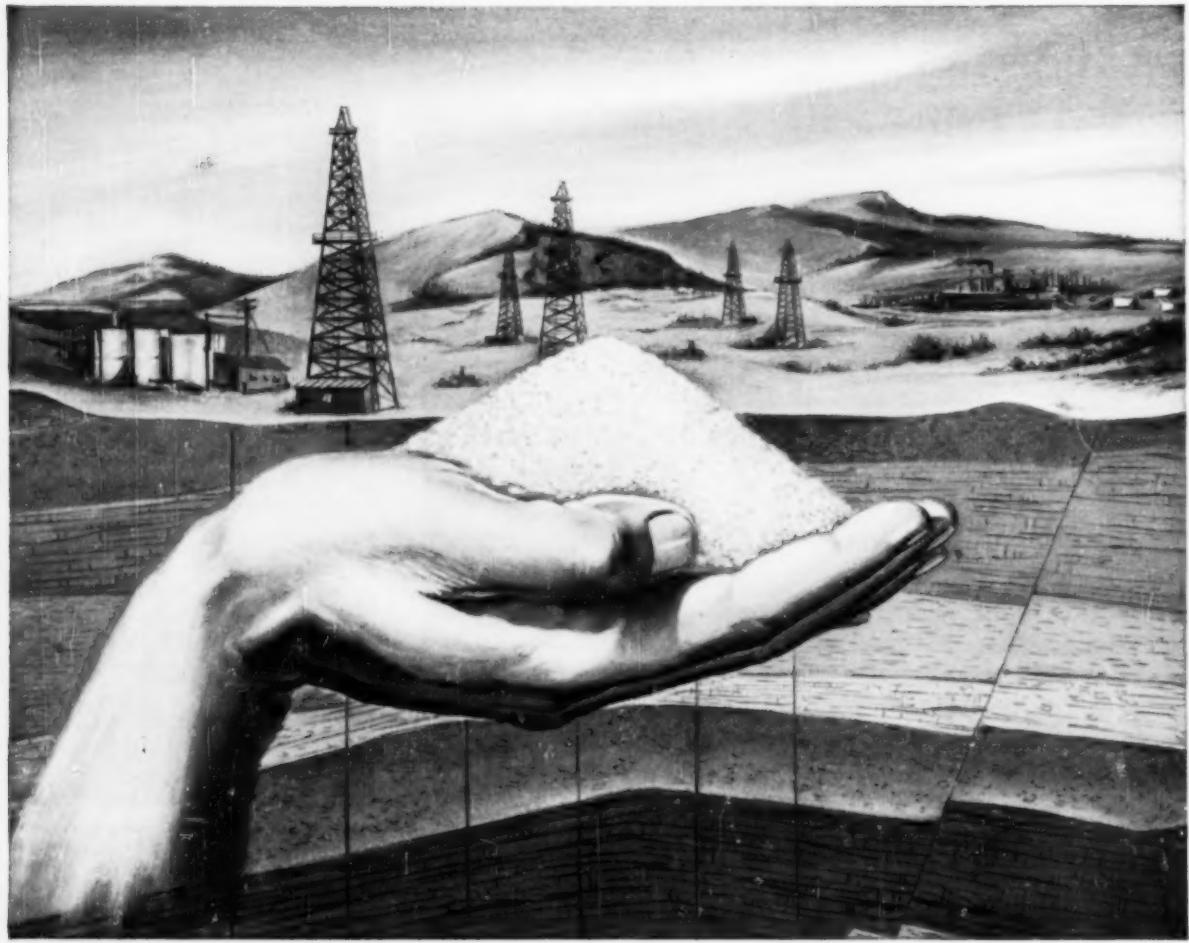


ON-THE-JOB—Girdler engineers supervise and direct all phases of construction. When the job is completed, experienced operating engineers will start up the plant, train operating personnel, run acceptance tests, and supply complete operating data.

### Want More Information?

Girdler's Gas Processes Division designs and builds plants for the production, purification, or utilization of chemical process gases; purification of liquid or gaseous hydrocarbons; manufacture of organic compounds. Write for Booklet G-35. The Girdler Corporation, Gas Processes Division, Louisville 1, Kentucky. District Offices: New York, Tulsa, San Francisco. In Canada: Girdler Corporation of Canada Limited, Toronto.





## "Lift-up powder" for tired oil wells

### How Celite filtration helps boost oil output

To BOOST THE OUTPUT of "tired" oil wells bordering on the limit of economic production, profit-conscious operators inject water under extreme pressure into the porous oil sandstone and force out the accumulated oil. But first, they filter this repressurizing water with Celite® to remove the suspended solids which would eventually clog the microscopic pores of the sandstone, thus blocking the flow of water. All waters contain at least a trace of these troublesome impurities.

Celite's ability to do an exceptional filtering job can be attributed to these important factors which make it unique among filter aids:

Carefully processed from the purest deposit of diatomaceous silica known, Celite is available in nine standard grades—each designed to trap out

suspended impurities of a given size and type. Whenever you reorder, you are assured of the same uniform, accurately graded powder received in your initial order. Thus, with Celite, you can count on consistent clarity in your filtrates—at highest rate of flow—month after month, year after year.

The secondary recovery of oil by water flooding is just one of many processes in which Celite has provided the absolute clarity vital to a successful operation. The proper grade of Johns-Manville filter aid will assure you the same results—regardless of the product or process involved. To have a Celite Filtration Engineer study your problem and offer recommendations, simply write Johns-Manville, Box 60, N.Y. 16. No cost or obligation.

\*Reg. U.S. Pat. Off.

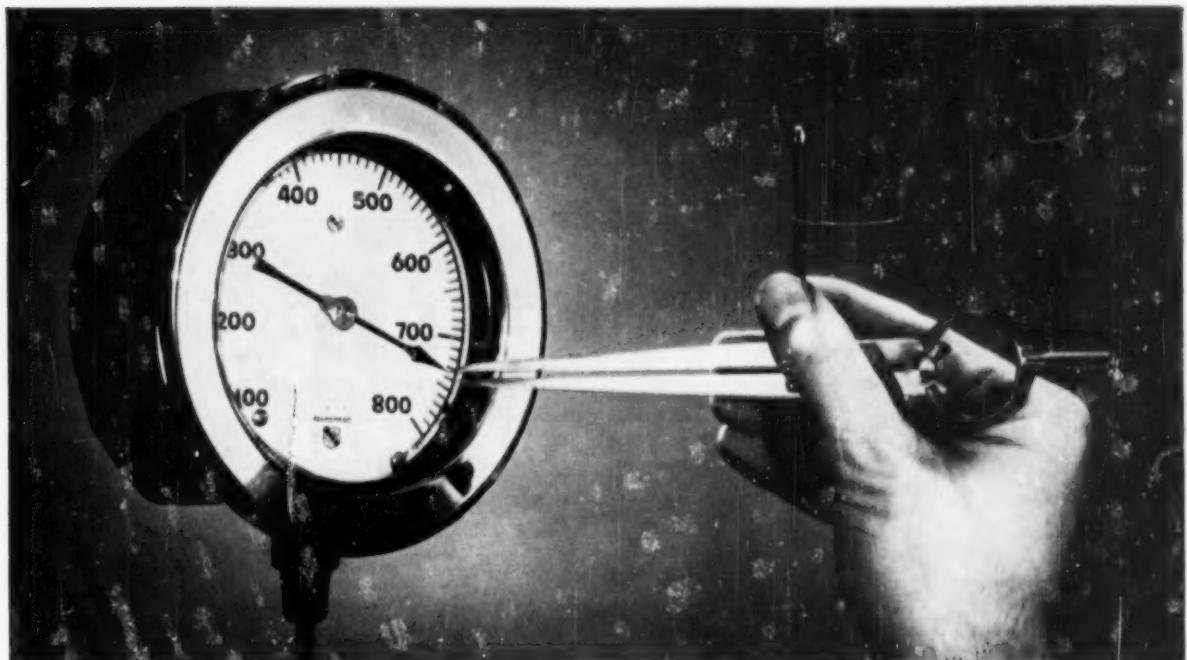


# Johns-Manville CELITE

## FILTER AIDS

# PRECISION CONTROL FOR PROCESS HEAT

with DOWTHERM, heat can be controlled within fractions  
of a degree at temperatures up to 750° F.



Dowtherm®, the modern heat transfer medium, maintains high temperatures within a fraction of a degree by simple pressure regulation . . . and gives this precise control uniformly over the entire process heating surface.

A liquid material used as a vapor heating medium in an entirely closed system, Dowtherm operates at high temperature, low pressure, and extends the advantages of steam-type heating to a much higher range of temperatures.

Dowtherm was created by the Dow research

team for the chemical, petroleum, paint, food and other process industries—has helped to increase production and even made possible new products.

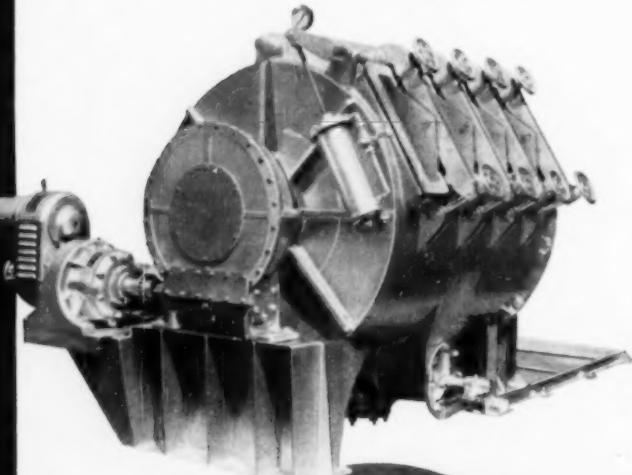
Countless installations in all industries have thoroughly proved the efficiency and cost reducing potentialities of Dowtherm. For complete information on these benefits and how they apply to your industry, write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department DO 3-1.

*you can depend on DOW CHEMICALS*



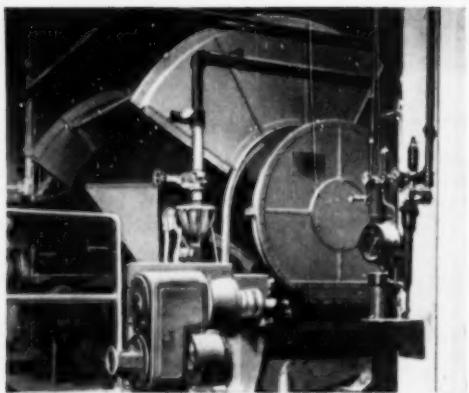
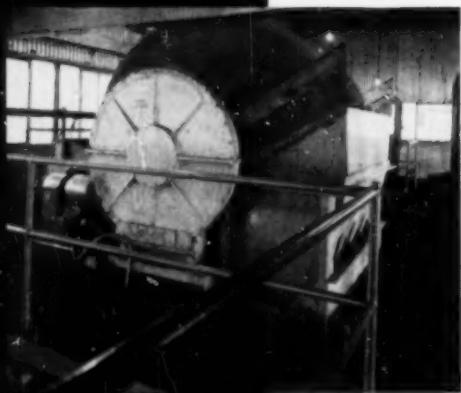
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built to  
fit your  
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Conkey Rotary Leaf Pressure Filters  
stay closed throughout operating  
cycle—you save on cloth and labor!



## CONKEY FILTERS FOR CHEMICALS

Conkey Rotary Disc Vacuum Filters clarify, wash solubles from solids and dewater.



Conkey Rotary Drum Vacuum Filter is a continuously operating filter for dewatering solids and washing solubles from accumulated solids.



Process Equipment Division

Send for  
Latest bulletin on Filters

# *An announcement*

to the processing industries

You can now have

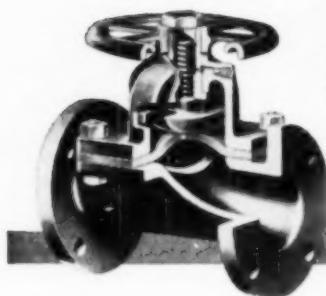
# TEFLON

DIAPHRAGMS

in HILLS-McCANNA *saunder's type*

**Diaphragm Valves**

Now, for the first time, Hills-McCanna offers TEFLON diaphragms in Saunders type diaphragm valves. With its well known resistance to temperatures, acids, alkalis, etc., TEFLON should make it possible to efficiently and economically valve substances that previously presented serious problems. These are full non-lubricated (not plasticized) TEFLON diaphragms, not merely a TEFLON facing applied to another material. If you have a valving problem that may be solved with TEFLON, we would appreciate having the opportunity to discuss it with you. Diaphragms are available for valve sizes  $\frac{1}{2}$ " through 4". Write, wire or phone, HILLS-McCANNA CO., 2438 W. Nelson St., Chicago 18, Ill.



**HILLS-McCANNA**  
*saunder's type diaphragm valves*

ALSO MANUFACTURERS OF CHEMICAL PROPORTIONING PUMPS • FORCE FEED LUBRICATORS • MAGNESIUM ALLOY SAND CASTINGS

**PHARMACEUTICAL  
PROCESSING  
ASSEMBLY**

ACETIC ACID  
AND OTHER  
FEED CHEMICALS



*If you process with ACETIC ACID, you need  
the corrosion resistance of glass  
plus the working strength of steel*

For across-the-board corrosion resistance in processes using acetic acid, *glassed steel is the most completely suitable material of construction available today*. Glassed steel is fully resistant to dilute solutions of acetic acid up to the boiling point and to all other concentrations up to at least 300° F. Even at temperatures above 300° F., glassed steel is sufficiently resistant to acetic acid attack to provide satisfactory, though not unlimited, service life.

Other materials are, of course, also used for acetic acid, but for wide application all are limited either by size, pressure, temperature, impurities, fragility, or cost. Glassed steel knows no such limitations.

Pfaudler glassed steel is resistant to *all acids except hydrofluoric*, even at elevated temperatures and pressures. With a new Pfaudler glass, it is possible to handle not only acids but also *alkaline* solutions up to a pH of 12 and 212° F.

To give it working strength, Pfaudler glass is fused to steel in huge furnaces at temperatures of 1500-1700° F. This high-temperature firing locks the glass to the steel and makes it hard and tough.

Pfaudler glassed steel reactors, in capacities from 5 to 3500 gallons, for internal pressures as high as 200 p.s.i., are commonplace in chemical processing today. These units are equipped with agitation, are usually jacketed, and are supplemented by a complete line of glassed steel pipe, fittings, and valves. Custom-built vessels as large as 8300 gallons, for severe chemical service, have been constructed. Glassed steel columns solve many serious corrosion problems.

Whenever you have an equipment problem requiring *corrosion resistance, durability, and versatility*, as well as the economy which these features provide, look to Pfaudler glassed steel for the solution.

Write for Bulletin 894-A-2, our new general catalog.

**PFAUDLER THE PFAUDLER CO., ROCHESTER 3, N. Y.**

*Engineers and fabricators of corrosion resistant process equipment since 1884*

*Factories at: Rochester, N. Y.; Elyria, Ohio; Leven, Fife, Scotland; Schwetzingen-Baden, Germany*

# Opinion and comment

## A PROFESSIONAL ATTITUDE

"The objects of the Institute are the advancement of chemical engineering in theory and practice and the maintenance of a high professional standard among its members."

The newly elected officers and directors of the Institute are conscious of their obligation to pursue the objects thus set forth. We who have long observed the chemical engineering scene know that chemical engineers, as a class, do endeavor to advance the profession and to maintain a high professional standard. Many do so whether they are members of A.I.Ch.E. or not, but in the Institute we have an effective means for organizing our efforts and so make them count more than is possible by individual initiative. To take a simple example, each of us could accomplish relatively little by devoting a few dollars a year to a personal effort in publishing chemical engineering literature. By joining forces, we have created and we maintain the excellent publications through which a permanent chemical engineering literature is being collected and preserved. No one of us gets direct benefit from every item published by A.I.Ch.E. Our publications are a service to the profession, to industry, to the nation and to the world. They involve not only modest money contributions from our members but also much devoted personal effort by many of them who organize symposia and solicit, write and review papers. Thus, through our publications we advance the profession and strive to create and maintain a high professional standard. This service is, in the best sense, a *professional activity*.

It seems to escape some men (most of whom are usually pretty young) that a profession involves *public service*. A professional man, to earn the rating, must be "ready to apply his special knowledge for the benefit of mankind," to use the words of Canons of Ethics for Engineers, to which A.I.Ch.E. subscribes. Throughout our civilization, that which sets the professional man apart from another man is the ideal of service to his fellow man. This ideal is the reason why, among thoughtful men of all cultural levels, the truly professional man is respected and revered, even though he may not become wealthy through his professional work. Usually those pursuits which bring material wealth take a man further and further from true professional status. Some men simply stop thinking professionally; others adopt new means for interesting themselves in public welfare and in aiding their profession. For example, a man who once devoted himself to basic research or teaching chemical engineers might become involved in management work to an extent which would make him financially independent but of no direct, personal service to his profession or his fellow man. He might finance scholarships or

found a chair in chemical engineering or serve on a university or government board. As many do, such a man might well find new ways to interest himself in public welfare, including active participation in the work of A.I.Ch.E.

In a professional society, such as A.I.Ch.E., there are opportunities for professional service for all kinds of men who have common interests. The youngest chemical engineer, who may as yet have little to offer, can accomplish a lot by participating in the Institute's work. Even if his only contribution is the toil he gives in exchange for the dues he pays, he is contributing in a way that multiplies his efforts. Whether the young man realizes it fully or not, these contributions are important and to a certain extent are at the professional level. Men who, with increasing age and experience, contribute personal time and effort to Institute work are being even more professional. In our ranks, numbering now more than 12,000, there is a tremendous potential for professional accomplishment. The measure of the success of the Institute administration in any year is the extent to which this huge potential is put to work for worthy professional objectives. We must find men who think professionally to such an extent that they are willing to sacrifice their own immediate advantage for the benefit of the profession as a whole. Without flag-waving or expectation of personal recognition they want to help.

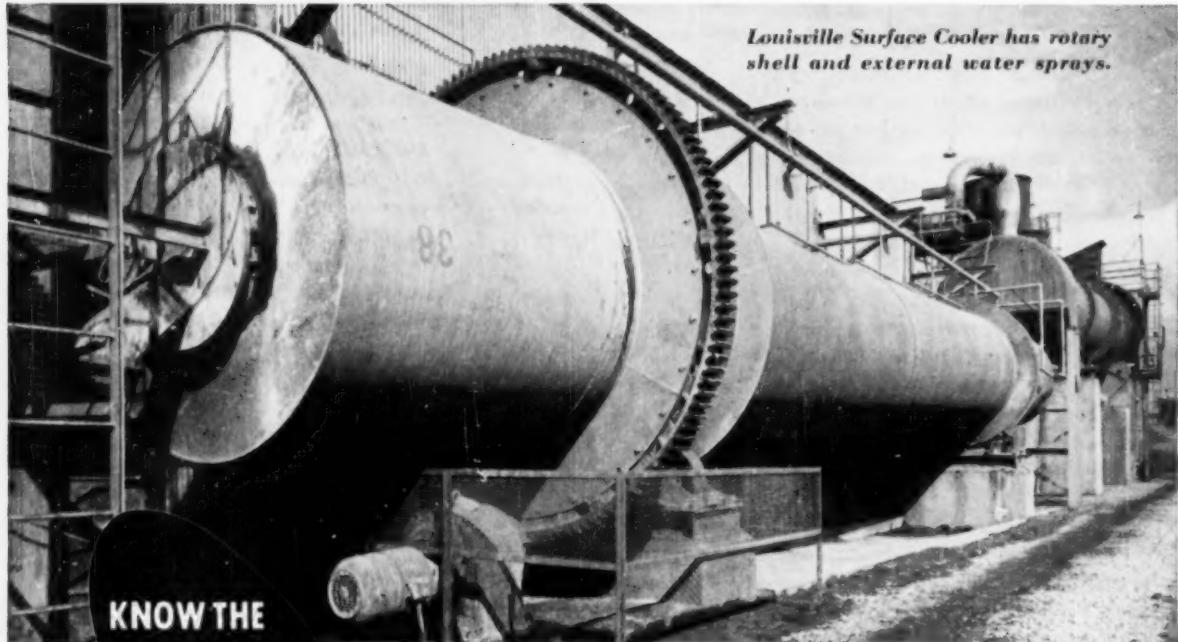
Fortunately, these greatly outnumber the few who seem to feel, quite sincerely, that our objects should be the social, economic and political advancement of the individual chemical engineer and the maintenance of a low professional standard among our members. That such sincere individuals do exist in our field is a sign that we need to exert ourselves more effectively to convince them of the value and the justice of the professional position and to see that they are reasoning from facts and not fallacies.

Save for a few people on the payroll of the Institute, the work done is on a purely voluntary basis. Many have found that a hard job well done in the Institute's program brings a sense of satisfaction hard to obtain otherwise. In national committees and particularly in our nearly fifty sections and almost a hundred student chapters scattered over the country, a large percentage of our members is actively participating in Institute work. In 1953 Council aims to increase member participation and the tempo of Institute accomplishment. While we hope to do an increasingly good job of utilizing the great member potential in work at the national level, we are conscious that a large and important job is to be accomplished by the members in the fifty sections operating in as many parts of the country.

W. T. NICHOLS  
President, A.I.Ch.E.

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# MULTISTAGE EJECTORS

## for high vacuum

VACUUMS that once were exclusive to the laboratory are being increasingly applied to large-scale industrial processes. The trend in this direction has led to design of multistage steam-jet ejectors to maintain high vacuum while handling commercial quantities of gases and vapors. While single-stage ejectors have been in use many years, widespread use of four- and five-stage high-capacity high-vacuum units has been confined to the past 10 to 15 years.

The part of the ejector in the vacuum industry can be better visualized when one considers the great volume of gases and vapors handled by an ejector at low absolute pressure. For instance, a medium-sized five-stage unit removing 20 lb./hr. of water vapor from a system at  $100\mu$  pressure is handling about 50,000 cu.ft./min., or about 24,000 liters/sec. The size and cost of mechanical equipment to handle these volumes is usually prohibitive. In addition, absence of moving parts in an ejector results in trouble-free operation with resultant low maintenance costs.

Figure 1 shows operating ranges of single- and multistage ejectors compared with other types of vacuum-producing equipment (1). Limits shown are based on economic and practical considerations. In systems where air leakage or release of gases and vapors is small or absent altogether, somewhat lower absolute pressures may be obtained with a particular unit.

Development of multistage ejectors has kept pace with the trend toward higher vacuums of various processes. As a result, practical operating range of multistage ejectors has been extended to below  $50\mu$ . This paper discusses operating characteristics of ejector elements with emphasis on multistage units. Design considerations for selection of suitable equipment are analyzed. Test methods for ejector equipment are described with a discussion on limitations and utility of available instruments.

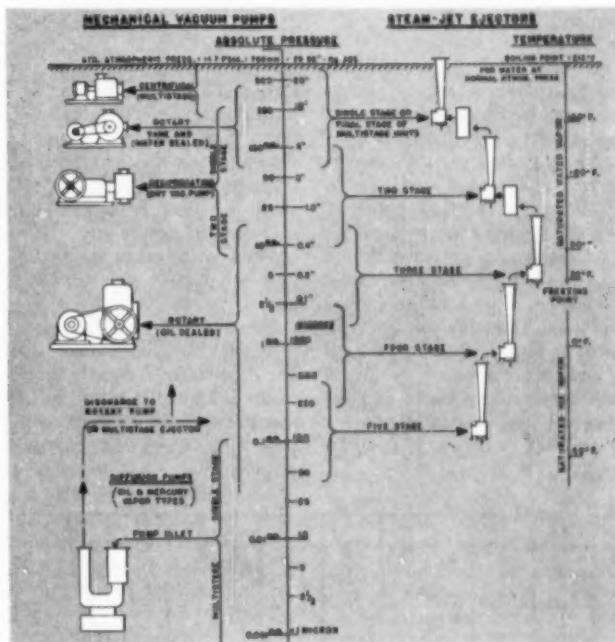


Fig. 1. Where vacuum equipment applies.



V. V. Fendrk is a product engineer with the Elliott Co., Jeannette, Pa. After graduation from the University of Pittsburgh in 1947 with a B.S. in chemical engineering, he joined Elliott Co. as a project engineer in the research and development department. For the past several years he has been engaged in assignments concerned with the design and application of process equipment.

V. V. Fendrk

A multistage ejector is a combination of several single-ejector elements so designed that operating ranges overlap to produce stability in the complete unit. The operating characteristic of each ejector element is basically similar. To understand the operation of a multistage unit, therefore, one must understand the operating characteristics of a single-stage ejector.

### Single-stage Ejector Characteristics

Figure 2 shows a typical ejector-performance curve at constant steam pres-

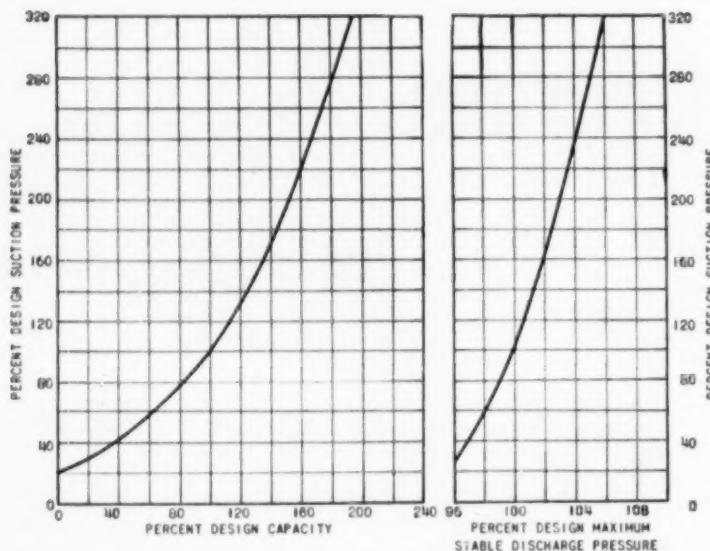


Fig. 2. Typical ejector performance curve for constant-motive steam pressure.

sure. In per cent of design conditions, capacity is related to suction pressure, at left, and to discharge pressure, at right. The capacity curve will be produced as long as system pressure at discharge is less than maximum stable pressure for a given suction pressure. If system back pressure exceeds maximum stable discharge pressure for a given load, the unit becomes unstable, and capacity is no longer a function of suction pressure. Unstable operation is usually characterized by bubble or fluctuation in suction pressure.

The discharge-pressure curve in Figure 2 indicates that operation against higher system back pressures is possible

at higher capacities for a given ejector stage. This characteristic is important in multistage ejectors, as will be shown later. Poorly designed ejectors do not always show this characteristic and at times may show a curve more nearly vertical. This is undesirable and unsatisfactory, especially if the curve bends back to cross the system-pressure line and causes the ejector to operate unstably at higher capacities.

Maximum discharge pressures may be increased by raising steam flow (Figure 3). For a fixed nozzle an increase in steam pressure is required. If the system pressure at discharge, therefore, is such that it causes the ejector to become

unstable at lower capacities, stable operation may be obtained by raising steam pressure. A clogged nozzle will have the same effect as lowered steam pressure.

If a unit is operating stably, discharge pressure may be raised to a value above maximum discharge pressure given in the curves before becoming unstable. The point at which the unit becomes unstable is known as the break point. The unit will not return to stable operation, however, until system pressure is reduced to the curve value. This point is called the pickup pressure. Operation in the metastable region between pickup and break points should be avoided, as momentary drop in steam pressure or rise in system back pressure may cause the unit to break, and it will not reestablish the suction pressure when operation again becomes normal.

For a given unit, capacity curves change somewhat with changing steam pressure, capacity being reduced with increased steam pressure. Reducing steam pressure below design value increases capacity until a point is reached where the unit becomes unstable and capacity falls off rapidly. For single-stage units discharging to atmosphere, this increase in capacity is small, while for units operating at high vacuum this effect may be appreciable.

A single-ejector element works through a limited ratio of compression (discharge pressure divided by suction pressure), the economic limit being about 10:1, with the normal limit somewhat less. If greater than 10:1 ratio is required, multistage design must be used. This 10:1 rule enables a simple check to be made on the minimum number of stages required to produce a given suction pressure. Practical considerations of operating economy usually suggest a lower compression ratio than 10:1.

#### Multistage-ejector Characteristics

The back-pressure and capacity relationships discussed above are of basic importance in the design of a multistage ejector. The following illustration is for a two-stage ejector; however, similar principles govern for any number of stages.

Combination of operating characteristics of two ejector elements into a two-stage unit is shown in Figure 4. Capacity of the second (lower vacuum) stage is plotted in terms of load to the first (higher vacuum) stage, the actual load to the second stage being greater than the load to the first. Where the first stage discharges directly into the second, load to the second stage consists of first-stage load plus first-stage operating steam. This type of operation is called noncondensing. Where a surface or direct-contact type of condenser is placed between stages, first-stage operating steam and condensable gases in the load are condensed, leaving only noncondensables plus

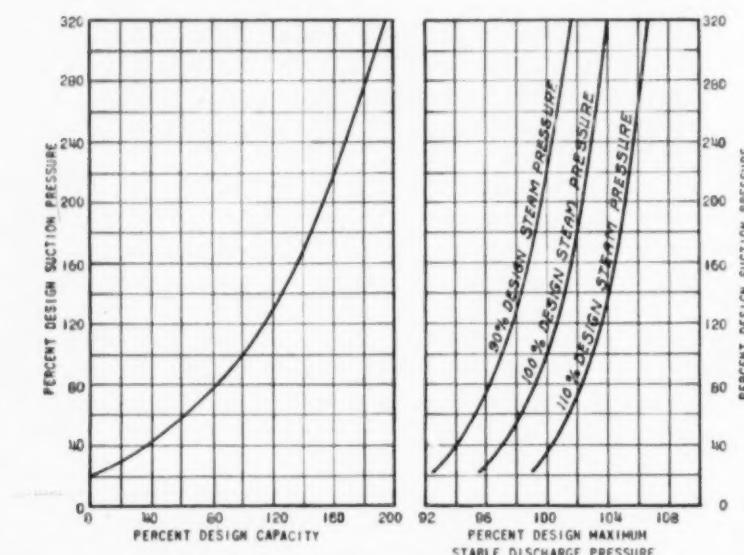


Fig. 3. Typical ejector performance curve with three different motive steam pressures.

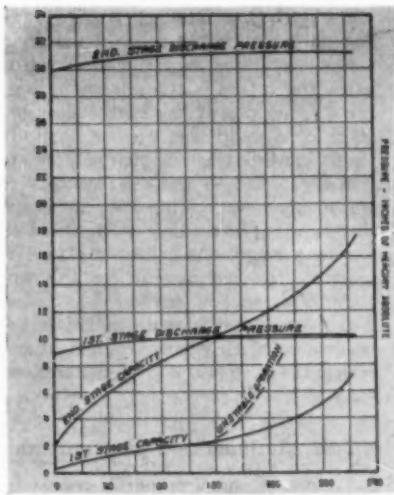


Fig. 4. Typical performance curves for a two-stage ejector.

vapor of saturation as load to the second stage. This is called condensing operation.

From Figure 4 it is apparent that the second stage must maintain an absolute pressure which is less than the maximum discharge pressure of the first stage; otherwise the first stage will become unstable, causing the first-stage capacity curve to fall off, as shown by the dotted curve. In matching operating characteristics, it is found that maximum discharge pressure does not increase with load as rapidly as the suction pressure of the following stage. This results in a point where discharge pressure and capacity curves cross and the unit becomes unstable. The point at which this occurs depends on design of the unit. By building in greater capacity in the second stage or greater back pressure in the first, the unit may be made to carry out over a greater range of capacity. It should be remembered, however, that this is done by increasing steam consumption and also cooling water to condensers in condensing units.

By similar matching of operating characteristics, a unit of any number of stages may be designed. Present economic and practical limit is five stages. First one or two stages in a high-vacuum unit generally are designed for noncondensing operation. This is necessary since load and motive gases and vapors must be compressed to a pressure somewhat above the vapor pressure of the condensing water to provide a temperature difference for condensation of vapors. Where quantities of air and other noncondensable gases are present, the partial pressure of the vapors entering the first intercondenser must be greater than the condensing-water partial pressure. Generally a five-stage unit will have the first two stages noncondensing, although occasionally the water available is cold enough to permit use of a condenser between the second and third stages. Four-stage ejectors usually

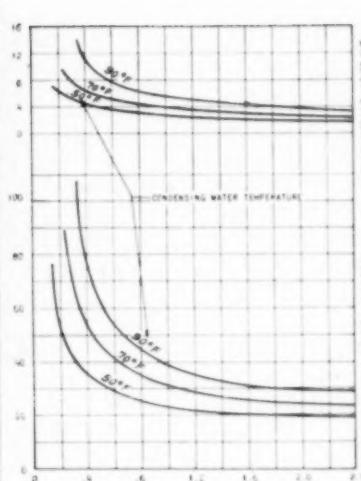


Fig. 5. Steam and condensing water rates for four-stage ejectors.

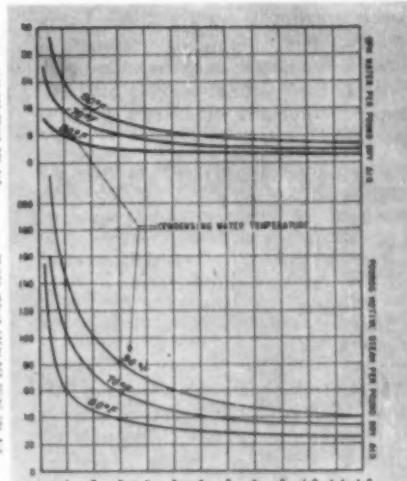


Fig. 6. Steam and condensing water rates for five-stage ejectors.

operate with the first stage noncondensing. Where two stages are operated noncondensing, the third-stage load consists of the sum of load plus operating steam from the first stage plus operating steam from the second stage.

Stages operating with suction pressures below 4.67 mm. absolute, the triple point for water, are provided with steam-heated diffusers to prevent formation of ice in the diffuser. In addition, steam nozzles must be of a special design to prevent freezing.

### Design Considerations

An engineer designing a high-vacuum process has control of several factors that will determine the original and operating cost of ejector equipment. Of great importance is elimination of air leakage into the system. In addition to being a direct load on the ejectors, air leakage, through partial-pressure effects, causes greater carryover of product being processed, thus further increasing the ejector load. In some cases the loss in product may be of importance.

Condensing water is of particular importance in design of ejector equipment. It always costs less to condense vapors and pump the liquid condensate to atmospheric pressure than to try to compress the vapors to atmospheric pressure. Not only are load vapors condensed, but in multistage units operating steam can be knocked out, thereby decreasing load carried by following units. As pointed out before, maximum condensing-water temperature will determine the stage in which compression condensation is possible. In spite of the foregoing, it is generally uneconomical to provide brine or refrigerated water

for condensing.

Water temperatures affect operating economy to a great extent. This is shown in Figures 5 and 6, where figures for steam and condensing-water requirements per pound of air load for four- and five-stage units are given for several water temperatures. Figures shown are based on average conditions and will vary somewhat for specific installations. Where load gases are part vapor or all vapor (and therefore can be condensed along with operating steam in the first intercondenser), steam-consumption figures will be somewhat lower.

It will be noted in Figures 5 and 6 that operating ranges for multistage units overlap to some extent. There is a maximum number of stages for maximum efficiency at any given pressure. A five-stage unit will normally require less steam and water than a four-stage unit for equal suction pressure and will have an appreciably lower shut-off pressure. However, as can be seen on the curves, a point is reached where a four-stage unit actually requires less steam than a five-stage unit. This is a result of the inherent losses between stages of a multistage unit. Similar overlapping occurs for one-, two-, and three-stage units.

Water requirements shown in Figures 5 and 6 can be varied in a particular design depending on availability of the water. Normally an economic evaluation is made using actual costs of steam and water. Where water is relatively plentiful, increased condensing water will result in lower steam requirements. The reverse is true where water is scarce. Waste disposal is an increasingly important factor, however, since

cost of treating water for disposal may be a factor in determining quantities of condensing water that may be used. Table 1 shows several possible combinations of water and steam for a specified operating point.

TABLE I.—POSSIBLE COMBINATIONS OF STEAM AND CONDENSING-WATER CONSUMPTION FOR AN EJECTOR HANDLING 1000 lb./hr. OF WATER VAPOR AT 5 mm. Hg abs. WITH WATER AT 70° F.

Steam, lb./hr.	Condensing water, gal./min.
3100	1200
3500	900
4100	570
4800	490
5600	440

**Types of Condensers.** Choice of surface- or direct-contact-type condensers for intercondenser service depends on needs of the process under consideration. Where it is necessary to recover condensed vapors uncontaminated by condensing water, where heat from operating steam is of importance, or where circulating-water contamination must be avoided owing to state or municipal laws, surface-type intercondensers are required. Surface-type intercondensers not only require more water, but water used must be relatively clean. Direct-contact condensers, on the other hand, normally require smaller quantities of condensing water, and, because water passages are relatively large, dirty water may be used. In addition to high original cost, surface-type units will generally require greater maintenance costs. Because of better cooling of non-condensable gases and subsequent reduction in load to following stages, use of direct-contact condensers will result in slightly lower steam requirements.

Direct-contact condensers may be either of the barometric or low-level type. The barometric type requires a water leg of 34 ft. for water removal, while the low-level type utilizes a pump for removal of condensate and cooling water. The barometric type is preferable because of lower maintenance costs. In addition, failure of pumping equipment on the low-level type will result in flooding of the entire system, an impossibility with the barometric type.

**Pressure.** Seasonal variation in condensing-water temperature may provide an opportunity for considerable savings in steam consumption. Ejector equipment is normally designed for stable operation with maximum expected water temperatures. Stages discharging to intercondensers are designed for a maximum discharge pressure which is higher than the vapor pressure corresponding to maximum water temperature. When colder condensing water is available, correspondingly lower vapor pressures permit operation of the condenser, and thereby the ejector discharge, at lower pressures. As was

pointed out before, maximum discharge pressures may be changed by changing steam pressure (Figure 3). With lower pressure available in the intercondenser, operating steam pressure of the stage discharging to the intercondenser may be reduced. Since steam flow is a direct function of absolute steam pressure, reduced steam flow is obtained. Oversize secondary ejectors must be provided however to operate at the lower booster condenser pressure. Throttling is profitable only when the load is largely condensable.

The reduction in steam pressure possible for a given reduction in water temperature may be determined by slowly reducing steam pressure until a bubble is noticed in the suction pressure of the stage under consideration. By slowly raising steam pressure until the bubble disappears, minimum steam pressure is determined. This should be recorded along with water temperature. Actual steam pressure should be slightly higher than minimum to allow some margin of safety over fluctuations in steam supply pressure.

It is usually possible to obtain minimum steam pressures and corresponding water temperatures from the ejector manufacturer. In fact, in many cases ejectors are designed for seasonal variation in water temperature, and effect of reduced steam pressure on ejector-discharge pressure is determined on test.

The discussion on variable water temperature, above, applies to any condenser serving ejector equipment except, of course, aftercondensers, which are vented to atmosphere. While it is possible, therefore, to throttle steam pressure of any stage discharging to an intercondenser, practical aspects usually limit this reduction in steam flow to the stage discharging to the first (lowest absolute pressure) intercondenser. The reason for this is that stages and intercondensers following the first intercondenser usually have small steam flows, and the savings are not worth while. The stage discharging to the first intercondenser, however, normally has the greatest steam consumption. This is especially true in four- and five-stage units where this stage is loaded by operating steam from the first or first two stages. Reduction in steam flow may amount to as much as 40% of the total. Where water temperatures reach maximum value for only short periods of time during the year, throttling steam pressure will result in an appreciable savings.

It was mentioned before that capacity curves change somewhat with changes in steam pressure, the change being more pronounced at low absolute pressures. This operating characteristic can be made useful where ejectors are serv-

ing a batch process which requires high vacuum near the end point of the process, while at the same time release of gases and vapors is at a minimum. Figure 4 shows that at low loads the second stage of a multistage ejector normally maintains first-stage discharge pressure considerably lower than is required for stable operation. This means, again, that steam pressure may be throttled on the first stage. As steam pressure is reduced, capacity increases; or, at constant load, suction pressure decreases. The magnitude of these changes is dependent on the particular equipment and system involved and must be determined by trial.

### Test Methods and Instruments

To obtain complete performance information for a multistage ejector requires two types of test. The simplest, and usually the only one that can be conveniently performed in the field, consists of a performance test of the complete unit. For this test, measured quantities of an available gas, usually air or steam, are permitted to enter the first-stage suction, and corresponding suction pressure is noted. These data result in a capacity curve for the entire unit. Maximum-discharge-pressure curves cannot be determined without special equipment since, with the exception of the last stage, all discharge pressures are fixed by the stage following the one under consideration. Therefore, the interstage pressure does not indicate the maximum discharge pressure.

Where more information is required, capacity and maximum-back-pressure curves are obtained for each stage. Normally this is done in the factory by placing a valve in the ejector discharge so that back pressure may be varied. Another method is to artificially load the following stage by bleeding steam into the suction and by this means to vary the pressure. Suction pressures and maximum stable discharge pressures are determined for several different measured loads and curves of the results plotted. Data obtained from an individual stage test can be combined, as shown in Figure 4, to determine performance of a complete multistage unit.

To obtain useful operating data on any ejector equipment requires accurate test instruments. Where ideal conditions exist, such as in a laboratory, many excellent instruments are available. Unfortunately, these are not always obtainable for field work in commercial installations.

To be suitable for field work a vacuum instrument, besides possessing some degree of accuracy, must meet the following specifications:

1. Portability.

- Sturdy construction.
- Stable calibration.
- Continuous reading.
- Calibration independent of properties of gas or vapor measured.

For pressures down to about 0.5 in. of mercury absolute, the usual range of single- and two-stage ejectors, the mercury manometer proves very satisfactory. From about 1 to 15 mm., covering three- and four-stage units, a di-n-butyl phthalate manometer, with one leg connected to a vacuum pump as reference, has proved acceptable. The reference-leg pressure in this case is measured by a portable McLeod gage. For pressures below 1 mm., special techniques are required.

Of the various gages available for use below 1 mm., none completely meet conditions specified above. The Pirani or hot-wire type of gage shows a lack of stability for the zero point. Ionization gages are far from portable, requiring considerable electrical equipment. In addition, frequent calibrations are necessary. The McLeod gage does not give continuous readings and requires a special set-up for condensable vapors. Trouble is also experienced from sticking mercury.

It should be remembered that in measuring ejector vacuum, moisture is always present. Even when the first stage is handling dry gases, there is some back diffusion of moisture from the steam jet. This usually results in constantly varying amounts or percentages of moisture in the gas to be measured. As a result, gages which depend

on constant gas properties for calibration cannot be accurately used. The McLeod gage suffers further in this respect since it cannot be used with condensable vapors. This problem is eliminated through use of a dry-ice trap to condense water vapor between the measured point and instrument and by using the Columbia modification of the McLeod gage. The Columbia modification permits several different compressions of the known volume of gas in the gage. By observing the readings for each compression the presence of condensable vapors may be determined by noting any abrupt change in readings. Readings showing condensable vapors must be discarded.

The field test method outlined above, while far from satisfactory, adapts itself to commercial ejector testing. Data obtained from tests conducted at the factory are used not only to prove guarantees, but also to provide valuable design data, which is used in the constant effort to improve equipment.

### Conclusion

The ejector, while appearing to be a rather simple device, has operating characteristics which must be well understood to permit maximum use and economy. Proper consideration of design factors will ensure a stable, economical unit.

### Literature Cited

- Compressed Air Magazine*, 52, No. 6, 144 (1951).

### Discussion

**G. J. Crites** (Stokes Machine Co., Riverston, N. J.): When something goes wrong with the operation of a multistage ejector, is it possible to diagnose reasonably the trouble without a lot of instrumentation?

**V. V. Fondrk**: The general procedure is to start at the last or highest absolute pressure stage and place in operation one stage at a time, working back towards the first stage. When a fluctuation in suction pressure is noted, or when the operation of the additional stage results in no appreciable improvement in vacuum, the source of trouble is indicated. Either the stage just placed in operation is not developing sufficient discharge pressure (possibly clogged nozzle) or the following stage has insufficient capacity. The latter condition may result from overload of this stage through faulty operation of the intercondenser, where one is used.

**E. L. Piret** (University of Minnesota, Minneapolis, Minn.): I understand that these ejectors have been proposed as meters for the measurement of small air flows. Could you tell us something about their use for such purposes?

**V. V. Fondrk**: Your comments also apply to ejectors handling large quantities of air. An ejector, provided it is not in such service that the diffuser is constantly corroding, will maintain a constant capacity-suction pressure relationship. The ejector characteristic curve may be obtained from the manufacturer or a calibration made at the installation, using measured quantities of air or the actual load gases. Once the suction-pressure-capacity relationship is established, a suction-pressure measurement will indicate the quantity of gases the ejector is handling.

*Presented at A.I.Ch.E. French Lick (Ind.) Meeting.*

## The First Hundred Years

More excerpts from the talks given at the recent Centennial of Engineering are here reproduced, to keep alive the thinking and enthusiasm which marked that historic gathering of engineers. (See also page 21.)

### The Clear Past

American state universities came into being with the laying of the cornerstone of the University of North Carolina in 1793. The first student was Hinton James who became a civil engineer. He entered the University early in 1795, was graduated in 1798, and left in a "record book" the titles of original and "exceptionally meritorious" compositions that he presented on Saturdays. Little is known of subjects he was taught as a student; but the titles of his original compositions show that he learned science, business, and economic geography—sound preparation for civil

engineers of his day. Later he became assistant to Chief Engineer Robert Fulton on navigation work, and superintendent of work for improving the Cape Fear River.

In America, where so many men have entered state universities, it is interesting to note that the first was to graduate and become a good civil engineer!

*History of Engineering Education*  
Frederic T. Mavis

### Engineering—Its Definition

The problem of the engineer is always essentially the same, regardless of the particular field of human action to which he turns his attention. His task is to make production as efficient, as unfailing and as easy as possible.

*The Machine Age of Farming*  
Robert P. Messenger

### The Dim Future

The American people have learned to do many things the expensive way. We are going to have to learn to keep things simpler and still perform the essential functions.

*Looking Ahead in Engineering Education*  
S. C. Hollister

### The Engineering Environment

While industry is interested mainly in applied research there is a growing need in its scientific investigations to become involved in basic science. Therefore, even closer cooperation with colleges, the climate of which in the past has been best for 'pure' research, should result to the benefit of the educational processes of both college and industry.

*Education—Engineer's Lifetime Job*  
Ralph L. Goetzenberger

# Altitude Test Facilities for Aircraft

## Engine Research

ONE of the largest gas-evacuating systems in the world is operated by the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics. The aircraft-engine research program of the N.A.C.A. had a modest beginning in 1920 with four single-cylinder test bedplates located in an aircraft hangar at Langley Field, Va., and some of the first investigations were performed on Liberty engine cylinders assembled with parts salvaged from scrap. Engine research facilities at Langley Field were increased to eight single-cylinder bedplates and one multi-cylinder bedplate, in 1934. It was soon realized that in order to keep abreast of the rapidly expanding aviation requirements, new and larger test facilities were necessary. Consequently, design was initiated in 1940 and construction was started on the Lewis laboratory at Cleveland, Ohio, in 1941. Although

the Lewis laboratory was designed for research on reciprocating engines, the advent of the jet engine required facilities continually transformed in light of present requirements, and today's research centers on full-scale and component parts of rocket, turbojet and ramjet engines, as well as research in the fields of higher temperature materials, lubricants, and engine fuels.

This paper describes various methods of aircraft-engine testing and explains why altitude facilities are necessary for research investigations. Reasons are given for the selection of the three basic types of altitude exhauster used at the Lewis laboratory (reciprocating, rotary lobe, and centrifugal), certain limitations of each type, and some of the operational problems encountered. The method of control and regulation is also discussed.

Altitude facilities in the laboratory duplicate conditions of pressure, temperature, and speed that are encountered by an aircraft in flight. Figure 1 shows how pressure and temperature decrease as altitude increases. The chart shows that air pressure constantly decreases from 14.7 lb./sq.in.abs. at sea level to 3.5 lb./sq.in. at 35,000 ft. In like manner, air temperature diminishes from an N.A.C.A. standard of 59° F. at sea level to -67° F. at 35,000 ft. From sea level to 35,000 ft., the pressure and temperature curves follow a similar pattern; however, above 35,000 ft., the similarity ceases to exist. As the altitude increases above 35,000 ft., the pressure continues to diminish until, at 100,000 ft., it reaches 0.2 lb./sq.in.abs.; whereas the temperature remains substantially constant, at -67° F., from 35,000 to 100,000 ft. Air that is supplied to a test engine in the laboratory does not necessarily follow the curves shown in Figure 1 since both the pressure and the temperature of the air entering the engine are increased by the speed of the airplane. For example, an airplane at 35,000 ft., flying at twice the speed of sound, produces a compression effect on the air entering the engine. This results in a pressure rise from 3.5 to 27 lb./sq.in. and a temperature rise from -67° to +250° F. Consequently, speed as well as altitude must be considered when test air conditions are being selected.

### Testing Methods

Engines are tested at the Lewis laboratory by various methods. One method is flight testing, where the engine to be tested is mounted on an airplane and taken aloft so that operational characteristics may be studied under actual flight conditions. Flight research data at very high speeds are obtained by dropping test-engines from the airplane, and research data are telemetered to monitoring stations on the ground. High-speed data are often obtained in this manner; however, drop testing is not



J. N. Vivien

Jean N. Vivien, starting as a marine engineering cadet, advanced through operating positions in industrial and utility steam power plants. Returning to college after eight years as an operator, he was awarded a B.S.M.E. by Tri State College in 1944 and then joined N.A.C.A., Lewis Flight Propulsion Laboratory as a mechanical engineer. Engineering work associated with design and operation of air and gas conditioning, pumping, piping, vacuum systems and related installations have become Mr. Vivien's specialty. He is presently supervising engineer of the process systems engineering section.



B. R. Leonard

After graduation from Purdue University with a B.S. in mechanical engineering in 1942, Bruce R. Leonard served in the U. S. Navy as an aviation ordnance officer until 1946. He was then engaged at the Boeing Aircraft Co., Seattle, Wash., in design and test engineering on the Stratocruiser, the B-47 and the B-52 bombers. In 1947 Mr. Leonard was employed at the Lewis Flight Propulsion Laboratory, Cleveland, where he is head of the Installation Design Unit which designs and installs various research projects, most of which require vacuum facilities.

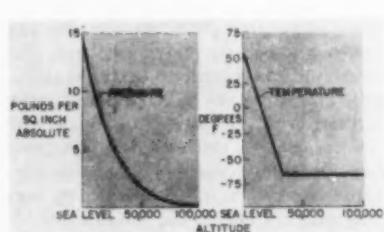


Fig. 1. Variation of atmospheric pressure and temperature with altitude.

used extensively, because a test engine is destroyed with each drop, and the results are not easily reproduced.

Another method, ground-static testing, consists in mounting an engine in a test cell and using no combustion air or exhaust facilities other than the surrounding atmosphere. Each of these methods has a definite place in research on aircraft engines, and the N.A.C.A., the military services, and others are using these methods today in their proper range of application.

The most extensive research can be conducted using a system wherein conditioned-air and -exhaust facilities may be furnished to a complete engine, or component parts in a wind tunnel or altitude chamber. An installation of the latter type is illustrated by the cycle diagram in Figure 2 which shows schematically a full-scale test engine housed in an altitude chamber with the inlet-air and exhaust-piping systems. The curves plotted beneath the piping diagram show the range of the principal system pressures and temperatures.

Starting on the left-hand side of the diagram, atmospheric air is usually compressed

to 50 or 112 in. Hg abs, with a resultant temperature rise of 142° or 360° F., respectively. The compressed air is first cooled in the compressor aftercooler to 100° F., and then may be further cooled to -70° F., if desired, by means of a large ammonia refrigeration system, before it passes through a shut-off valve, which is operated from a central control room. The air then enters the test-cell area. The research engineer controls the throttle valve to set the desired flow and the temperature controller where a particular altitude and flight-speed temperature are duplicated by reheating. This conditioned air is then supplied to the engine. The exhaust gas leaves the engine at a maximum temperature of 3500° F. The combustion air is passed through the engine with a minimum temperature rise during calibration testing when no combustion takes place. The exhaust pressure varies from 3.4 to 30 in. Hg abs. as it leaves the engine. The gas then enters a primary cooler, from which the exit temperature ranges from 40° to 600° F., passes through the back pressure or regulating valve, and is further cooled to 125° F., or less, before entering the exhausters. Finally, the gas is discharged to the atmosphere.

### Examples of Research Installations

The use of altitude facilities may be illustrated by four typical research installations found at the Lewis laboratory.

Figure 3 is a photograph of a full-scale engine installed in the altitude chamber that is shown schematically in Figure 2. The hatch, which is shown in the open position, is closed and bolted before the test is started. Compressed air at the scheduled pressure and temperature is supplied through the bulkhead on the left. It then goes through the air inlet of the engine, the compressor section, the combustion chambers, the turbine, and out the tail pipe. The exhaust gas is removed to the right by the laboratory exhauster system, which is capable of evacuating this tank to simulate altitudes of over 60,000 ft.

Research problems often concern the component parts of the engine. Figure 4 shows a large multistage axial-flow compressor from a turbojet engine, driven by a variable-frequency 15,000-hp motor. Conditioned air is supplied through the surge chamber shown on the left, and discharges into the two vertical pipes over the compressor.

Figure 5 shows a single combustion-chamber setup where combustor operation may be studied using only one of the several combustors that normally power an engine. Laboratory systems supply air at the left and remove exhaust gas at the right, and in order to make the results applicable to the engine conditions, the air supplied to the combustion chamber is heated and compressed to stimulate the action of the engine compressor. The heated gas discharged from the burner is

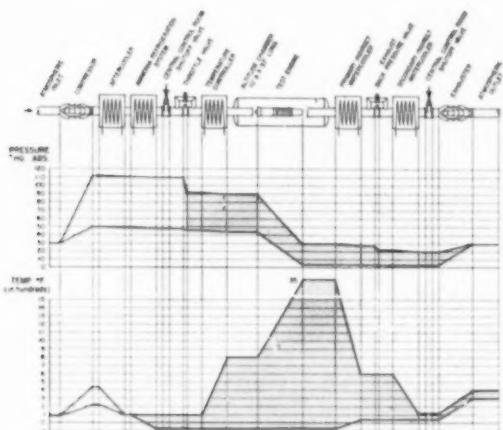


Fig. 2. Altitude test flow diagram.

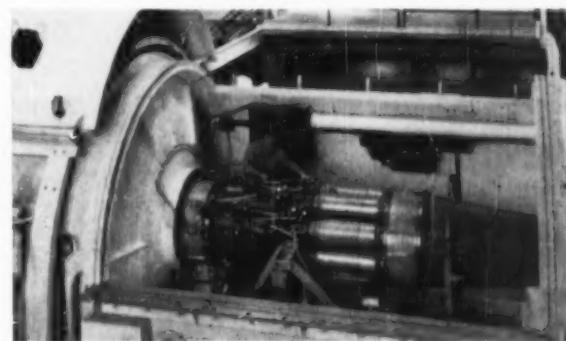


Fig. 3. Altitude chamber mounting of full-scale turbo-jet engine.

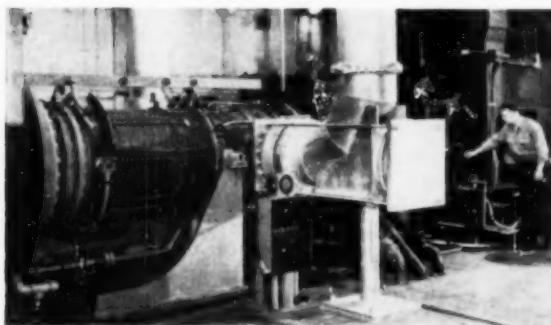


Fig. 4. Axial-flow compressor test installation.

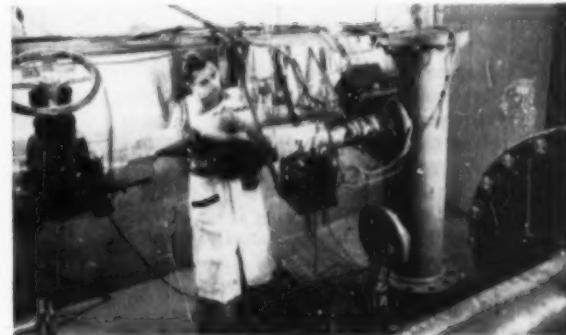


Fig. 5. Single combustor research setup.

also subjected to the same conditions as those encountered in flight.

A typical turbine research installation is shown in Figure 6. Heated, compressed air is supplied to a full-scale turbine through the overhead pipes, and the turbine discharges into a large pipe in the background. Mounted to the right of the turbine is an absorption dynamometer.

Figure 7 is a diagram of the altitude wind tunnel located at the Lewis laboratory where full-scale engines are operated under simulated flight conditions. The engine may be mounted in a wing or fuselage section, and study made of the aerodynamic conditions around the engine as well as through it.

Air is circulated within the tunnel at any desired speed up to 500 miles/hr. by the fan shown in the upper left corner of the tunnel. Refrigeration equipment, located in the building shown to the right, operates with tunnel heat exchangers to lower the tunnel temperature to the altitude requirements. The exhausters that evacuate the tunnel are shown in the lower left of the diagram. Pressure in the tunnel is adjusted by varying the number of exhausters in use and by throttling the make-up air. The make-up air requirements of engine combustion are supplied through the air-drying equipment.

Tunnel conditions of speed, pressure, and temperature are set during operation. The system is balanced so that while make-up combustion air is supplied ahead of the engine, the products of combustion are removed to the rear of the engine through the exhaust scoop. From the exhaust scoop, products of combustion are cooled and sent through the exhausters which discharge to atmosphere. The exhaust equipment is capable of evacuating the entire tunnel to 1.7 lb./sq.in.abs., and the refrigeration system can reduce the air temperature to  $-67^{\circ}$  F., which duplicates atmospheric conditions at 50,000 ft. above sea level.

There are over 100 test installations at the Lewis laboratory, similar to those described, that are served with combustion-air and altitude-exhaust facilities. Careful thought is given to scheduling and dispatching of the facilities to obtain the maximum economy of test time.

### Vacuum Systems

In general the main vacuum or altitude-exhaust systems at the Lewis laboratory have been integrated by means of interconnecting piping so that machines of different types and capacities may be operated in parallel and/or in series for maximum capacity and minimum pressure, or separately for maximum system flexibility.

Machinery now in use contains large-scale representatives of several common commercial types. There are reciprocating machines rated at about 51,000 cu. ft./min. each, rotary-lobe-type exhausters ranging to 24,000 cu.ft./min. each, and centrifugal equipment ranging from 30,000 to 275,000 cu.ft./min. in capacity.

The first research facility to be completed for use in the early 1940's was the altitude wind tunnel. The requirements of this tunnel were set up in the light of reciprocating aircraft engines.

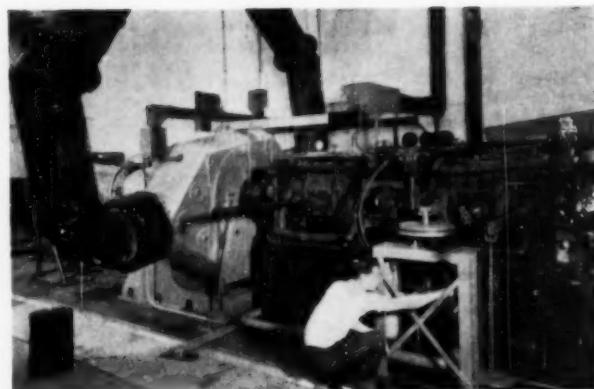


Fig. 6. Turbine power test setup.

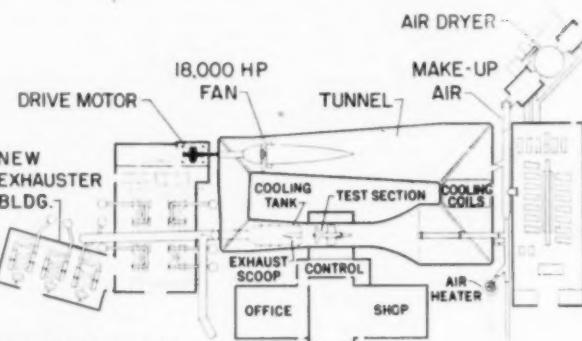


Fig. 7. Schematic diagram of altitude wind tunnel.

The design point of the tunnel was set at a 30,000-ft. ceiling corresponding to an absolute pressure of 8.8 in. Hg abs.

The pressure drop through the ducting to the machine suction was of the order of 1 in. Hg at the maximum altitude. Also, some discharge losses occurred through the piping and the muffler. Hence, the exhausters had to pump from a suction pressure of about 7.5 in. Hg abs. to a discharge pressure of about 30 in. Hg abs. Pressure ratio under these conditions is 4. Approximately 200,000-cu.ft./min. capacity was required to handle the planned engine range.

It was found at the time the design work was in progress that reciprocating machines could be delivered sooner than other types and were also most economical under the particular requirements of this installation. Accordingly, four reciprocating machines were installed in the initial exhaust group at this location. Figure 8 shows operating characteristics of these machines, and Figure 9 is a photograph showing the general appearance of the machines.

Other reasons favoring selection of reciprocating machinery may be listed as follows:

1. Although the tunnel-design point was fixed at 30,000 ft., some data were needed at higher altitudes. Therefore,

exhausters that could handle pressure ratios as high as 8 were considered desirable. The reciprocating exhausters offered this advantage over other available types.

2. Special automatic controls could largely be eliminated.
3. Rotary-lobe-type positive-displacement compressors have many of the advantages of the reciprocating machines, but the large capacities required would have resulted either in many smaller size units or in larger machines for which design and operating experience was lacking.
4. Some design and operating experience was available for reciprocating machines as steel-mill blowers in the 50,000-cu.ft./min. class.

Operating experience with this installation has been reasonably favorable during the eight years it has been in operation. In common with most of the facilities at the Lewis laboratory, it was not long before aircraft-engine research requirements were such that higher altitude testing in the altitude wind tunnel became desirable, and the reciprocating exhausters were called upon to deliver higher vacuums than originally specified.

The increased vacuums imposed greater forces on the machines, and additional care and maintenance became necessary. The higher discharge temperatures made proper cylinder cooling

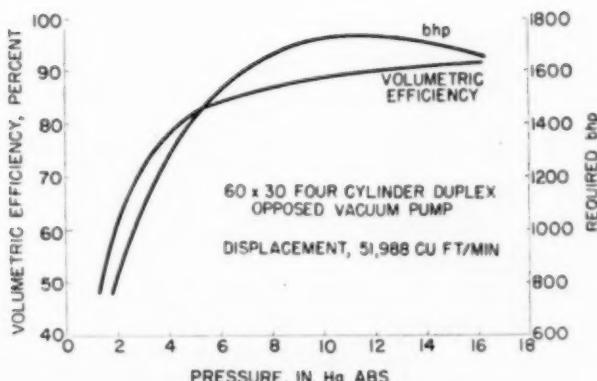


Fig. 8. Reciprocating exhauster performance.

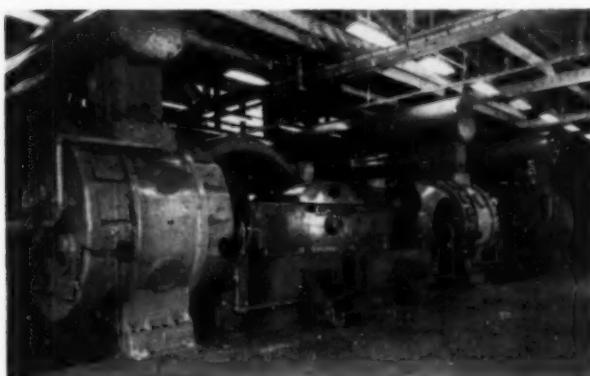


Fig. 9. Reciprocating exhausters.

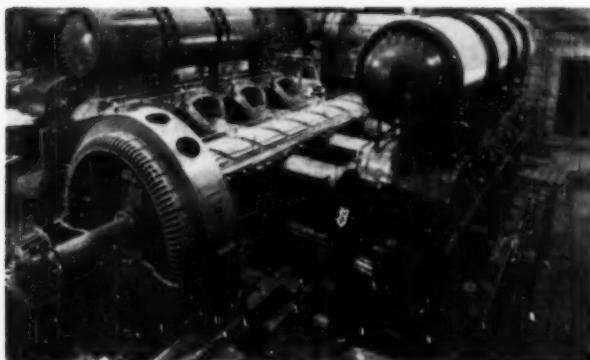


Fig. 10. New wind-tunnel exhausters.

and lubrication more difficult. Study of the operating difficulties resulted in an auxiliary oil system for starting and in lubricant changes that brought maintenance to a reasonable level.

Recently it became possible to replace the original wartime 60-in. diam. cast-iron pistons of these machines with an aluminum alloy. The pistons weighed approximately 4000 lb., and this weight was reduced to approximately 1400 lb./cylinder when the replacement was made. The weight reduction has resulted in decreased maintenance as well as easier starting.

At the present time the exhaust capacity of the altitude wind tunnel is being increased by approximately 75% by the addition of more machines. Reciprocating machines have again been selected for the installation. In this case the machines use a multithrow crank-shaft arrangement with more cylinders and are more compact than that of the original four machines.

The new machines, of which there are three, consist of eight cylinders arranged as shown in Figure 10. Displacement of each machine is approximately 50,000 cu.ft./min.

### Rotary Exhausters

While work on the altitude wind tunnel was in progress, another test facility, called the Engine Research Building, was under construction. Somewhat different in purpose from the altitude wind tunnel, this building housed a few full-scale and a number of small-engine and engine-auxiliary test stands. Exhaust from each of the many test installations was ducted to a main header collection system and then through exhausters to the atmosphere. Some idea of the extent of this system is shown in Figures 11 and 12, where control-room panels outline the system schematically.

Because of a wide variation in exhaust-gas loads anticipated, together with a need for separation of loads during simultaneous operation of several smaller test installations, there was some advantage to a greater number of smaller exhausters as opposed to a few large units.

In addition to load consideration, the original altitude design point of this system was set higher than that of the altitude wind tunnel. Therefore, the machines had to handle higher pressure ratios.

Specified research load conditions could be met by exhausters with a total capacity of 120,000 cu.ft./min. and a pressure ratio of about 10. This pressure ratio was too great for efficient single-casing compression with any type compressor readily available at the time, so that reciprocating, centrifugal, or rotary compressors each were on a relatively equal footing in that respect.

The fact that the exhaust gas would carry large quantities of free moisture (due to the wet-spray exhaust-gas coolers proposed for test stands) gave favorable consideration to the rotary machines. Rotary machines operate well with wet gas since free water is useful in providing rotor cooling and sealing. In the case of both reciprocating and centrifugal compressors, however, moisture-laden gas creates undesirable operating conditions that necessitate installation of good separators at the machine suction.

Bids were taken on both centrifugal and rotary positive-displacement exhausters with over-all installation costs finally favoring the rotary machines. There are six rotary machines at this location. Four of the machines are rated 23,500 cu.ft./min. each and two at 12,000 cu.ft./min. each.

A general installation diagram of one of these machines is shown in Figure 13, and a typical performance curve in Figure 14. One rather unique feature of two-stage operation with this type of installation is the self-regulation of the loads on each stage by the check-valve.

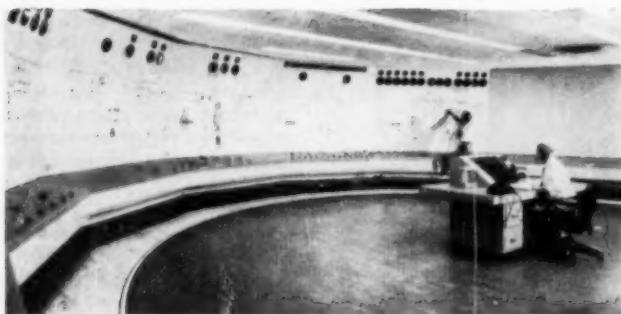


Fig. 11. Central control room.

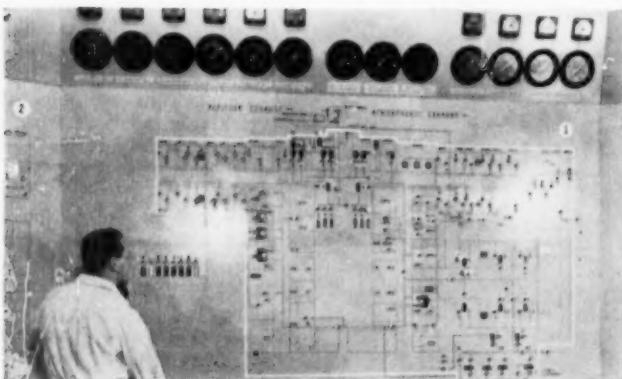


Fig. 12. Exhaust control panel.

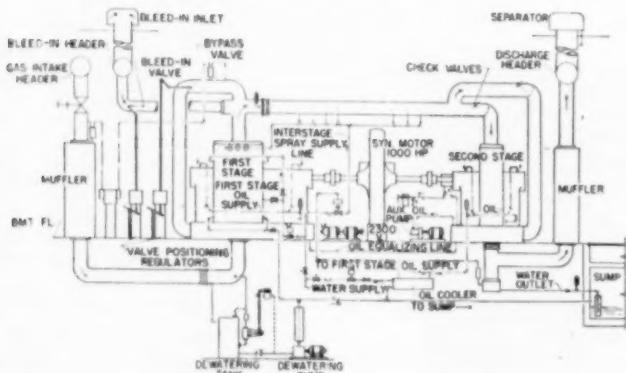


Fig. 13. Schematic diagram of rotary exhauster.

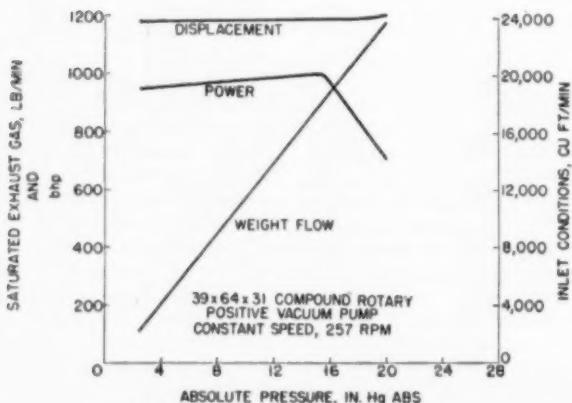


Fig. 14. Rotary exhauster performance.

arrangement at the suction to the second stage. Since these are positive displacement blowers operating at a fixed speed and essentially a constant pressure ratio, suction conditions are often such that the first stage alone is sufficient to pump the exhaust gas to the atmosphere. When this happens, the second-stage by-pass check-valve opens.

Load regulation on these machines may be accomplished by opening a bypass valve on the first stage or by admitting make-up air through the atmospheric bleed-in valve. The combination of the two control components allows good regulation with a pneumatic-pressure-regulator system.

The rotary exhausters operate with a constant supply of water to seal the clearance between the rotating lobes and the stator ends, the pressure seals formed between the lobes of the rotors and the cylinder surfaces of the casings and the line of rotor contact.

Operating experience with these machines has been relatively good since their installation some seven years ago.

### Centrifugal Exhausters

The last war was fought almost entirely with reciprocating-engine airplanes, but toward the end of the European phase, interest shifted to high-speed jet-powered aircraft. This brought about a change in emphasis on aircraft-engine research programs in this country.

An aircraft jet engine is a large user of air, and early jet-engine research programs were greatly handicapped by lack of flow capacities at available research facilities. Tests had to be conducted at sea-level conditions and results projected by altitude predictions. Rather than take the time to build entirely new facilities at the Lewis laboratory, plans were made to convert those already existing to a plant size sufficient to handle jet engines then being planned.

Studies on modernizing all the air-supply and -conditioning facilities, as well as the exhaust-gas systems serving the Engine Research Building, were undertaken. New test stands were constructed, larger exhaust-gas piping and exhausters were installed, and most of the research program shifted to work on jet engines and their cousins in the missile field, such as ram jets and rockets.

As previously mentioned, the original exhauster equipment, exhaust-gas coolers, and piping were designed for direct water-spray cooling with saturated gas for exhauster consumption, and this combination somewhat favored the wet-seal-lobe-type exhausters.

Emphasis with jet-engine research is in the direction of higher altitudes under

greater ram or speed conditions; therefore, high capacity at high altitudes has usually favored the adoption of indirect exhaust-gas coolers for this service wherever possible.

Some idea of the exhaust-gas volume reduction possible at higher altitude with indirect cooling equipment may be seen in Figure 15, which shows exhaust-gas specific volume plotted against temperature for various pressures or altitudes when the gas is cooled by the addition of water and again when no additional water is added to the products of combustion.

Point *A* indicates the end point of a gas-saturation-cooling process when no sensible cooling has been accomplished. Corresponding to point *A*, the specific volume of the gas mixture for each starting pound of dry gas is approximately equal to 330 cu.ft. Saturation temperature, reached by cooling the gas, occurs at 96° F. when initial temperature of the gas was 3000° F.

When 75° F. cooling water is available, as it is most of the time, it is possible to cool the gas mixture from point *A* to point *B*, which reduces the gas volume to approximately 185 cu.ft./lb. of dry gas, but this requires handling and cooling large quantities of water to dissipate heat, at the low-temperature level of the condensing process. The cooler, therefore, tends to become elaborate and large.

Alternately, if the same pound of gas were cooled to point *D*, or 75° F., in an

indirect cooler, no water vapor would be added to the gas and the final volume would be approximately 150 cu.ft./lb. of dry gas. Point *C* illustrates the fact that for equal gas volume for both the direct and indirect cooling processes, it is necessary to reduce gas temperature to less than 50° F. Usually the cooling process is carried to about 100° F., as shown at point *E*, with little penalty. Thus, the cooling requirements of jet-engine exhaust gas at high altitudes and high temperatures generally favor an indirect method to hold exhaust-gas volumes to the lowest possible quantity and also to reduce the water-cooling problem.

From this study, the decision to install indirect coolers was arrived at even though they required much more operating care and maintenance than the spray coolers.

Studies were made of the exhausters, then, as a part of the over-all exhaust-gas cooling, piping, and pumping problems. It was finally determined that centrifugal exhausters would best fit the problem. Some aspects of the problem considered may be listed as follows:

1. The high-altitude requirements of this installation greatly favored staged compression. In order to maintain a 50,000-ft.-altitude pressure condition, exhauster inlet pressure would run about 3 in. Hg abs. or lower, and with discharge losses through piping and coolers, a pressure ratio of about 10 to 1 would be required.

2. The low densities and high volume flow of the exhaust gas made large equipment an economic necessity. This requirement generally eliminated positive-displacement lobe-type machines. Reciprocating machines might have been used in units up to 50,000-cu.ft./min. capacity each, but it was finally determined to install four 100,000-cu.ft./min. centrifugal exhausters. It was felt that over-all first cost, as well as operating costs, favored centrifugal equipment in this location.

Figure 16 shows the general arrangement of these machines.

As installed, the three machines in the foreground may operate in series with the last machine or all may operate in parallel, depending on system-vacuum requirements. In addition, all four of these machines can be paralleled and operated as a unit in series with the older positive-displacement lobe-type machines. This combination gives the greater system capacity at the higher altitudes where two-stage compression is necessary.

The three machines in the foreground of Figure 16 have 2500-hp. motors and the farthest one has a 4000-hp. motor. At the time of the initial design work, tentative research schedules indicated that the three 2500-hp. machines would always be operated under low density inlet conditions, for example, at 3 in. Hg abs. discharging at 10 in. Hg abs. On the other hand, the fourth machine would often act as a second compression stage to the first three, taking gas at a suction pressure of about 9 in. Hg abs. and discharging it at atmospheric or nominally 30 in. Hg pressure.

Under the series arrangement, owing to variation in exhaust-gas density at the two nominal suction levels, the fourth machine could handle the output of the other three. This condition of operation fixed the need for a 4000 hp. drive motor contrasted to the other centrifugal exhausters.

All four of the exhausters are identical in design except for driving-component sizes. Rated compression ratio is 3½ at 100,000 cu.ft./min. For regulation, these machines operate at variable speed ranging from 1200 to 2800 rev./min. A hydraulic coupling provides a means of speed control and is used in conjunction with pneumatic pressure-sensing diaphragms and regulators on the exhaust-suction header to maintain preset header pressures with wide load changes. Good pressure regulation is extremely important to keep research exhaust conditions stable. Minimum flow requirements are met by a bleed-in valve at each machine suction, which is operated with the speed control to prevent surging at low flows.

Exhauster design details are generally in accordance with standard industrial centrifugal-blower-construction practice. The rotor assembly has four steel-fabricated wheels, the blades are backward curved, and the diameter of the inlet wheel is 60 in.

Actual operating experience with this installation has been generally good during the five years it has been in service. The fluid couplings have had several changes made from the original installation. Coupling impeller design was improved and more cooling surface provided to maintain lower oil temperatures under high-coupling load conditions. Considerable work has been done

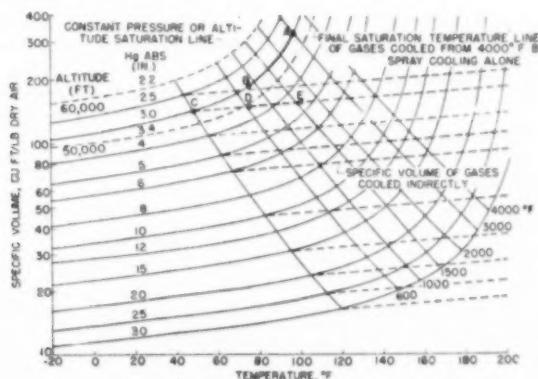


Fig. 15. Specific volume of air-water vapor mixtures.

1. Moisture content of gas = 8 per cent by weight as it leaves engine.
2. Air and exhaust gas have comparable values.

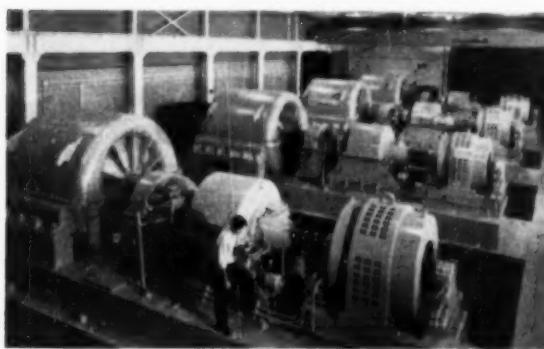


Fig. 16. Centrifugal exhausters.

with the automatic speed controls which maintain suction conditions at a constant point.

The nature of the suction load is far from steady, and header-pressure fluctuation often was complained about by the research staff. Gradually, sufficient operating experience and control development provided acceptable operating conditions. The greatest difficulty with a straight speed-control system seemed to be that the high inertia of the machine and its coupling caused a lag during a rapid load change.

As operating experience developed with the centrifugal machine installation, it was found that high-altitude scheduling of the services was considerably less than anticipated initially. The bulk of the research schedule could be met with single-stage operation of this machine group. However, as previously stated, three of the machines in this group did not have enough power for normal operation from an inlet pressure of 10 in. Hg abs. to a discharge pressure of 30 in. Hg abs.

Figure 17 shows partial-operating characteristics of these machines when operated single stage at one selected speed. After some minor piping changes, the three 2500-hp. machines were tried under nominal suction conditions of 10 in. Hg abs. Initial operation showed that the load response of the speed control system was inadequate to prevent serious exhauster surging since motor rating required operation at the low-displacement surge end of the operating curve.

Remotoring of the three 2500-hp. machines was briefly considered but soon rejected because of many reasons, not the least of which was high cost. It was then decided to try another control system on these machines for the special requirements of single-stage operation. No change was made on the 4000-hp. second-stage machine; it was adequately powered to work properly with the original speed-control system.

Between the piping headers to and from the three 2500-hp. machines, however, a single discharge-end-to-suction-end-by-pass line with control valve was installed. This control valve was automatically adjusted to maintain constant machine flow conditions

over a satisfactory range. The speed of the machines was manually set to obtain the nominal 10 in. Hg suction conditions; all operations following were then at the same speed. Pressure drop across one of the machine aftercoolers was used for flow indication, and the resulting impulse transmitted to the by-pass bleed-valve pneumatic operator to maintain flow above the surge range.

The 4000-hp. machine is used for swing load while the three 2500-hp. machines operate on a fixed-base load. Exhauster drive equipment permits considerable overload for short periods so that there apparently are no adverse effects from momentary load peaks. Operating experience has shown this control system satisfactory. When the machines operate as the first stages of a two-stage setup, control is returned to the original speed setup by a simple transfer switch.

#### Central Control Room

One of the particularly unique features of the exhauster equipment is the interrelationship of one machine to another. As was pointed out, each type of machine was purchased for a particular job, and yet all the machinery may be operated collectively as a unit. This is accomplished by a system of cross piping and remotely controlled valves. The nerve center for this operation is the central control room, shown in Figure 11.

The service dispatcher's desk is located in the center of the room so that he may readily see the five control panels that form a semicircle around his desk. Each of the five control panels supervises and directs a particular service, as required by the individual test cells. The service dispatcher maintains contact with each research test cell and with the equipment operators by means of a direct-wire telephone service.

The far right-hand panel controls the exhaust systems that were described previously, and Figure 12 gives a close view of this panel with a typical panel layout. The lines on the panel are color coded with each colored line representing a building wall or a process pipe. A white line surrounds the panel and represents the outer walls of the building that houses the research setups served by the exhaust facilities. Brown lines mark the various research test cells, and red and green lines represent the altitude and atmospheric exhaust-piping systems. Green and red lights on the pipe lines indicate the locations of the exhausters. A green light represents an exhauster available for operation, and a red light represents a machine that is in operation. Pairs of white and blue lights represent valves in the open or closed position. There are more than 300 valves, ranging in size from 3 to 72 in. in diameter, which are controlled from these panels. Knobs and indicating lights on the panel apron comprise a part of the safety system. Should an emergency arise somewhere in the building and the equipment operator be unable to reach his controls, each major piece of equipment supplying the altitude services could be shut down from the central control panel.

The remaining four panels in the central control room operate exactly as the one just described; however, each one supervises an entirely different system. The second panel handles the 10-lb./sq.in. refrigerated-air supply system, the third panel controls the distribution of the 40-lb./sq.in. combustion air, the fourth panel supervises the 125 and 450-lb./sq.in. air system, and the fifth panel is used for distribution of the 2-lb./sq.in. engine-cooling air.

By means of this central control system, air supply and engine exhausts are directed through an intricate system of valves, machines, and piping to the many test installations. Consequently, simplified control is maintained over the complex test and service equipment in order that the maximum number of research activities may operate simultaneously.

#### Future Exhaust System Growth

A new research facility at the Lewis laboratory incorporates many improvements in not only the altitude-exhaust-vacuum system, but also all the other process systems needed to provide altitude-test conditions. The high air requirements of present-day aircraft engines and those of the near future made early construction of this facility a necessity. With proven research techniques for a model, new equipment has been designed to allow simulation of flight conditions for high ranges of speed, altitude, and engine size.

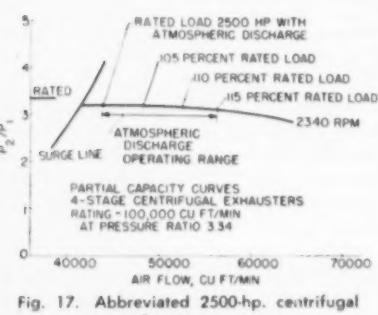
The exhauster equipment for this installation was designed cooperatively by the manufacturer and the Lewis design staff, who used data collected as a result of aircraft centrifugal-compressor research programs for much of the basic design knowledge.

One result of this cooperative design program has been procurement of centrifugal compressors somewhat ahead of their normal industrial development time.

The largest exhauster unit is driven by a 16,500-hp. motor which is directly connected to three centrifugal exhausters.

Impeller design has been improved and refined to a point where a pressure ratio of 2/wheel has become possible as compared to average present-day ordinary commercial design practice, where pressure ratios are about 1.4/wheel. Displacement rating of the low-pressure stage is 275,000 cu.ft./min. per casing with a wheel 70 in. in diameter.

This equipment may be connected with the older exhauster machines previously described for common paralleling or other arrangements designed to increase utility. While 72-in.-diam. exhaust piping is common in the older installations at Lewis laboratory, the new facility has required 120-in.-diam. piping for the same service. The large pipe sizes have not proved particularly difficult to handle structurally, but the necessary shut-off and throttling valves that these systems required presented new and interesting design problems.



# THE THEORY OF UNSTEADY-STATE DISTILLATION

## BATCH-DISTILLATION CALCULATIONS

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The recent availability of automatic computers has made it practical to use stepwise numerical mathematical methods that were previously far too laborious for engineering calculations. The present paper discusses various mathematical approaches to some complex distillation phenomena. The same situation undoubtedly exists for other unit operations such as absorption, adsorption, diffusion, extraction, ion exchange, dialysis, and others.

MUCH of the earlier theoretical work in batch distillation was carried on with the assumption that the McCabe-Thiele procedure was valid for finding the relationship between product and still-pot compositions. The further assumption of zero holdup was usually made. The method of calculation, outlined by Smoker and Rose (12) involves solution of the Rayleigh equation

$$\ln \left( \frac{S_2}{S_1} \right) = \int_{x_{s1}}^{x_{s2}} \frac{dx_s}{x_D - x_s} \quad (1)$$

A solution can always be obtained, either analytically or graphically, if the  $x_D$  vs.  $x_s$  relationship is known.

The preceding equation produced several derived equations and correlations of value. Calculated series of curves based on zero holdup and total reflux conditions (9) were found valuable in showing the maximum possible separation that could be obtained with a given column and mixture. Similar calculations were made for finite holdup conditions (10), assuming again that total reflux conditions prevailed, i.e., that the spread between product and still-pot compositions was the same as that obtained under total reflux.

The following general equation for batch distillation was derived from an over-all material balance on the more volatile component in a binary mixture (6):

$$S = e^\lambda \left\{ k + \int_{x_{s1}}^{x_{s2}} \frac{[-Cf'_N(x_s, \dots) + f'_H(x_s, \dots)] dx_s}{(x_D - x_s) e^\lambda} \right\} \quad (2)$$

where

$$\lambda = \int \frac{dx_s}{x_D - x_s}$$

and

$C$  = condenser holdup.

Functions  $f'_N(x_s, \dots)$  and  $f'_H(x_s, \dots)$  are derivatives of the terms defined by the equations

$$h = f_H(x_s, \dots)$$

and

$$x_D = f_N(x_s, \dots)$$

where

$h$  = holdup of more volatile component.

Colburn and Stearns (1) derived a similar equation without, however, completely separating the variables:

$$\ln \frac{S_1}{S_2} = \int_{x_{s2}}^{x_{s1}} \frac{dx_s}{(x_D - x_s) - (\Sigma H) \left( \frac{dx_h}{dS} \right)} \quad (3)$$

They also derived the following equation for the operating line in batch distillation:

$$y_n = R' x_{n+1} + (1 - R') \left[ x_D - \left( \frac{t-n}{t} \right) \frac{(\Sigma H)}{S_0} \frac{dx'_h}{d \left( \frac{S}{S_0} \right)} \right] \quad (4)$$

where

$H$  = total holdup, both vapor and liquid, in the column

$x_h$  = average composition of total holdup

$x'_h$  = average composition of holdup above the  $n$ th plate

$R'$  = reflux ratio expressed as  $L/V$

$t$  = total number of theoretical plates in the column

They pointed out that the effect of holdup is twofold. The added term in the denominator of Equation (3) suggests that the separation with holdup should be less sharp than with no holdup. However, the spread between  $x_D$  and  $x_s$  may be increased by the presence of holdup, thus tending to improve the separation. They also stated that the disadvantage of equations, such as (2) and (3), is that the equations cannot be solved without prior knowledge of the course of a distillation, and thus cannot be used in predicting this course.

Differential equations of batch distillation, based on plate-by-plate material balances, were derived independently by one of the authors and by Pigford (5). As shown below, these equations do not lend themselves readily to solution.

The most recent papers on this subject (7, 8) present results obtained by the stepwise numerical solution, by the method of first differences, of finite difference equations derived from the

differential equations. The method of calculation is summarized in the papers of Rose and Williams (11), and Rose, Johnson and Williams (8).

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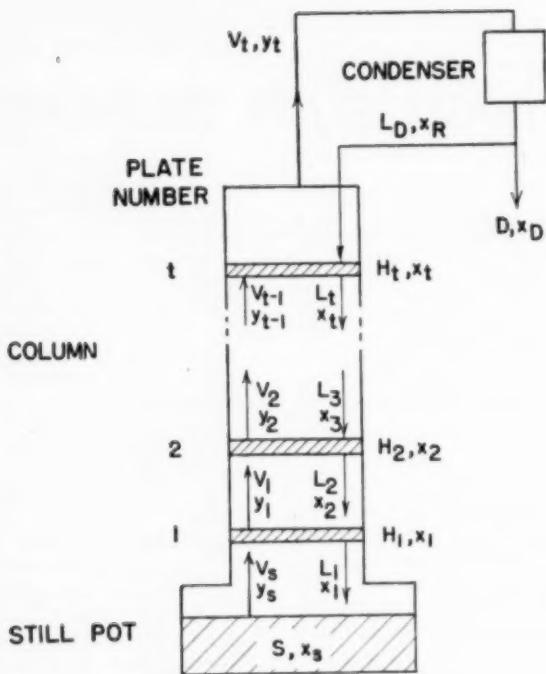


Fig. 1. Diagram of a batch-distillation column.

### Notation

$V$  = rate of vapor flow, mole/unit time, from still or any plate

$L$  = rate of liquid flow, mole/unit time

$D$  = rate of product removal, mole/unit time

$H$  = liquid holdup on each plate, mole

$S$  = liquid in still pot, mole

$x$  = mole fraction of more volatile component in liquid phase

$y$  = mole fraction of more volatile component in vapor phase

$R$  = reflux ratio,  $L/D$

### Subscripts:

$s, 1, 2, \dots, (t-1), t$  refer, respectively, to the still pot, plates 1, 2, ...,  $(t-1)$ , and top plate.

$D$  refers to distillate.

Other notation is introduced as needed.

**Differential Equations and Difference Equations and Their Use.** The remainder of this paper contains (1) derivation and properties of the system of differential equations that describe composition changes on each plate during batch distillation and (2) derivation of finite difference equations for batch distillation and explanation of their use with automatic computers.

### Assumptions Involved in Derivation of Plate Differential Equations.

These are as follows:

1.  $V_1 = V_2 = \dots = V$ .
2.  $L_1 = L_2 = \dots = L$  (and therefore  $D = V - L$ ).
3. Vapor holdup is negligible.
4.  $x_n$  is uniform across plate  $n$ , and equal to the  $x$  leaving the plate.
5. A total condenser is used.
6. Condenser and line holdup is negligible, and therefore  $y_t = x_{t+}$ .
7. The holdup on each plate is constant, and  $H_1 = H_2 = \dots = H$ .

A batch-distillation column is diagrammatically represented in Figure 1.

**Derivation of Plate Differential Equations.** For plate  $n$ , during the time interval  $d\theta$ , the plate receives

$$\begin{aligned} & H dx_n \\ \therefore & H dx_n = [V y_{n-1} + L x_{n+1} \\ & - V y_n - L x_n] d\theta \quad (5) \\ & \frac{dx_n}{d\theta} = \frac{1}{H} [V(y_{n-1} - y_n) + L(x_{n+1} - x_n)] \quad (6) \end{aligned}$$

Similarly, for the top plate,

$$\frac{dx_t}{d\theta} = \frac{1}{H} [V y_{t-1} - L x_t + D x_D] \quad (7)$$

The similar material balance of more volatile component in the still pot may be written, for the interval  $d\theta$ ,

$$\text{Gain} = L x_1 d\theta$$

$$\text{Loss} = V y_s d\theta$$

$$\text{Change in number of moles} = d(S x_s) = S dx_s + x_s dS$$

$$\therefore S dx_s + x_s dS = (L x_1 - V y_s) d\theta \quad (8)$$

$$\frac{dx_s}{d\theta} = \frac{1}{S} \left[ L x_1 - V y_s - x_s \left( \frac{dS}{d\theta} \right) \right] \quad (9)$$

But  $dS/d\theta$  is the rate of removal of material from the still pot, and, since  $V$  and  $L$  are assumed constant throughout the column,

$$dS/d\theta = L - V = -D \quad (10)$$

Substituting (10) in (9),

$$\frac{dx_s}{d\theta} = \frac{1}{S} [L x_1 - V y_s + D x_s] \quad (11)$$

Since  $R = L/D$ , Equations (6), (7), and (11) may be rewritten:

$$\left. \begin{aligned} \frac{dx_t}{d\theta} &= \frac{D}{H} [(R+1)y_{t-1} - Rx_t - x_D] \\ \frac{dx_n}{d\theta} &= \frac{D}{H} [(R+1)(y_{n-1} - y_n) + R(x_{n+1} - x_n)] \\ \frac{dx_s}{d\theta} &= \frac{D}{S} [Rx_1 - (R+1)y_s + x_s] \end{aligned} \right\} \quad (12)$$

$[V y_{n-1} + L x_{n+1}] d\theta$   
moles of more volatile component, and loses

$$[V y_n + L x_n] d\theta$$

moles. The net gain of more volatile component on the plate is

$$\frac{dS}{d\theta} = \frac{S_0 d \left( \frac{S}{S_0} \right)}{d\theta} = -D \quad (13)$$

It is desirable to eliminate time as the independent variable. This may be done by writing  $S_0$  as the total moles of charge, and rewriting (10) as

Then, defining  $F = S/S_o$  as the fraction of charge remaining in the still pot at any time,

$$d\theta = -\frac{S_o}{D} dF \quad (14)$$

The quantity  $d\theta$  may now be removed from Equations (12), and the basic differential equations for batch distillation in a plate column may be written, subject to the assumptions listed above:

$$\left. \begin{aligned} \frac{dx_t}{dF} &= -\frac{S_o}{H} [(R+1)y_{t-1} - Rx_t - x_B] \\ \frac{dx_n}{dF} &= -\frac{S_o}{H} [(R+1)(y_{n-1} - y_n) + R(x_{n+1} - x_n)] \\ \frac{dx_s}{dF} &= -\frac{1}{F} [Rx_1 - (R+1)y_s + x_s] \end{aligned} \right\} \quad (15)$$

Equations for the top plate and still pot may be written in forms which more closely resemble the equations for the intermediate plates. These forms may be preferable in computation.

$$\left. \begin{aligned} \frac{dx_t}{dF} &= -\frac{S_o}{H} [(R+1)(y_{t-1} - x_B) + R(x_B - x_t)] \\ \frac{dx_s}{dF} &= -\frac{1}{F} [(R+1)(x_s - y_s) + R(x_1 - x_s)] \end{aligned} \right\}$$

**Comparison of Differential Equations with Those Derived by Other Investigators.** The above Equations (15), though independently derived, closely resemble those obtained by other investigators. Pigford and Marshall (4) write the following material balance around plate  $n$  in a plate column:

$$\left. \begin{aligned} H \left( \frac{\partial x_n}{\partial \theta} \right) + h_v \left( \frac{\partial y_n}{\partial \theta} \right) \\ = U(y_{n-1} - y_n) + L(x_{n+1} - x_n) \end{aligned} \right\} \quad (16)$$

This is identical with (6) if vapor holdup,  $h_v$ , is assumed to be negligible.

Pigford, Tepe, and Garrahan (5) express the equations in the form

$$\left. \begin{aligned} F' \frac{dx_s}{d(1-F')} &= x_s + Rx_1 - (R+1)y_s \\ \frac{H}{S_1} \frac{dx_n}{d(1-F')} &= R(x_{n+1} - x_n) - (R+1)(y_n - y_{n-1}) \end{aligned} \right\} \quad (17)$$

where  $(1-F')$  = the fraction of initial still contents distilled over, and  $S_1$  = initial still contents after equilibrium is reached, i.e., charge minus total holdup.

Since  $d(1-F') = -dF'$ , the equations may be rewritten

$$\left. \begin{aligned} \frac{dx_s}{dF'} &= -\frac{1}{F'} [Rx_1 - (R+1)y_s + x_s] \\ \frac{dx_n}{dF'} &= -\left(\frac{S_1}{H}\right) [(R+1)(y_{n-1} - y_n) + R(x_{n+1} - x_n)] \end{aligned} \right\} \quad (18)$$

Then, since

$$F' = \frac{SS_o}{S_1 S_o} = F \left( \frac{S_o}{S_1} \right)$$

by substituting

$$\left( \frac{S_o}{S_1} \right) dF \text{ for } dF'$$

the Equations (15) are obtained.

(19) then becomes

$$\left( \frac{S}{H} \right) \left( \frac{dx_s}{dF} \right) + t \left( \frac{dx_h}{dF} \right) = -\left( \frac{S_o}{H} \right) (x_s - x_B) \quad (21)$$

Letting  $\Sigma H$  = total holdup in the column, neglecting vapor holdup, multiplying by  $H$ , and substituting  $S/S_o$  for  $F$ ,

$$\left. \begin{aligned} \frac{S dx_s}{d \left( \frac{S}{S_o} \right)} + (\Sigma H) \frac{dx_h}{d \left( \frac{S}{S_o} \right)} \\ = S_o (x_B - x_s) \end{aligned} \right\}$$

$$d \left( \frac{S}{S_o} \right) = \left( \frac{1}{S_o} \right) dS$$

$$\therefore S \left( \frac{dx_s}{dS} \right) = (x_B - x_s) - (\Sigma H) \left( \frac{dx_h}{dS} \right) \quad (22)$$

$$S = (x_B - x_s) \left( \frac{dS}{dx_s} \right)$$

$$= -(\Sigma H) \left( \frac{dx_h}{dx_s} \right) \quad (23)$$

But

$$(\Sigma H) \left( \frac{dx_h}{dx_s} \right) = \frac{dh}{dx_s} = f'_H(x_s, \dots)$$

Making a material balance around the entire column,

$$\left. \begin{aligned} \left( \frac{S}{H} \right) \frac{dx_s}{dF} &= -\frac{S_o}{H} [(R+1)(x_s - y_s) + R(x_1 - x_s)] \\ \frac{dx_1}{dF} &= -\frac{S_o}{H} [(R+1)(y_s - y_1) + R(x_2 - x_1)] \\ \vdots &\vdots \\ \frac{dx_t}{dF} &= -\frac{S_o}{H} [(R+1)(y_{t-1} - x_B) + R(x_B - x_t)] \end{aligned} \right\}$$

Adding the above equations,

$$\left. \begin{aligned} \left( \frac{S}{H} \right) \frac{dx_s}{dF} + \frac{dx_1}{dF} + \dots + \frac{dx_t}{dF} \\ = -\left( \frac{S_o}{H} \right) (x_s - x_B) \end{aligned} \right\} \quad (19)$$

$$\left. \begin{aligned} \therefore -S + (x_B - x_s) \left( \frac{dS}{dx_s} \right) \\ = f'_H(x_s, \dots) \end{aligned} \right\}$$

$$\frac{dS}{dx_s} - \frac{S}{(x_B - x_s)} = \frac{f'_H(x_s, \dots)}{(x_B - x_s)}$$

Solution of this yields

$$S = c^k \left\{ k + \int \frac{f'_H(x_s, \dots) dx_s}{(x_B - x_s)^{c^k}} \right\} \quad (24)$$

which is the same as (2), except that condenser holdup has been neglected in this derivation.

Similarly, from (22),

$$dx_s = \left[ (x_B - x_s) - (\Sigma H) \left( \frac{dx_h}{dS} \right) \right] \frac{dS}{S}$$

$$\frac{dS}{S} = \frac{dx_s}{(x_B - x_s) - (\Sigma H) \left( \frac{dx_h}{dS} \right)} \quad (25)$$

$$\ln\left(\frac{S_1}{S_2}\right) = \int_{x_{n_2}}^{x_n} \frac{dx_s}{(x_D - x_s) - (\Sigma H)\left(\frac{dx_h}{dS}\right)} \quad (3)$$

This is the equation derived by Colburn and Stearns. Their operating-line equation may be obtained by a similar summation of the plate equations. Making a material balance from plate  $n$  and around the condenser:

$$\left. \begin{aligned} \frac{dx_{n+1}}{dF} &= -\frac{S_o}{H} [(R+1)(y_n - y_{n+1}) + R(x_{n+2} - x_{n+1})] \\ \frac{dx_{n+2}}{dF} &= -\frac{S_o}{H} [(R+1)(y_{n+1} - y_{n+2}) + R(x_{n+3} - x_{n+2})] \\ \vdots &\vdots \\ \frac{dx_{t-1}}{dF} &= -\frac{S_o}{H} [(R+1)(y_{t-2} - y_{t-1}) + R(x_t - x_{t-1})] \\ \frac{dx_t}{dF} &= -\frac{S_o}{H} [(R+1)(y_{t-1} - y_t) + R(x_D - x_t)] \end{aligned} \right\}$$

Since  $x_D = y_t$ , the sum of the equations is

$$\begin{aligned} \frac{dx_{n+1} + dx_{n+2} + \dots + dx_{t-1} + dx_t}{dF} \\ = -\frac{S_o}{H} [(R+1)y_n - Rx_{n+1} - x_D] \end{aligned} \quad (26)$$

Since  $R' = L/V$  and  $R = L/D$ ,  $R = R'/(1-R')$  and  $R+1 = 1/(1-R')$ .

$$x'_h =$$

$$\frac{x_{n+1} + x_{n+2} + \dots + x_{t-1} + x_t}{t-n}$$

∴

$$\begin{aligned} dx_{n+1} + dx_{n+2} + \dots + dx_{t-1} + dx_t \\ = (t-n)dx'_h \end{aligned} \quad (27)$$

Assuming vapor holdup = 0,  $\Sigma H$  = total holdup =  $tH$ . Then

$$(t-n) \frac{dx'_h}{d\left(\frac{S}{S_o}\right)} = -\frac{S_o}{H} \left[ \left( \frac{1}{1-R'} \right) y_n - \left( \frac{R'}{1-R'} \right) x_{n+1} - x_D \right] \quad (28)$$

Rearranging (28),

$$\begin{aligned} -\left(\frac{\Sigma H}{t}\right) \left(\frac{t-n}{S_o}\right) \frac{dx'_h}{d\left(\frac{S}{S_o}\right)} &= \left(\frac{1}{1-R'}\right) y_n - \left(\frac{R'}{1-R'}\right) x_{n+1} - x_D \\ \therefore y_n &= R'x_{n+1} + (1-R') \left[ x_D - \left(\frac{t-n}{t}\right) \left(\frac{\Sigma H}{S_o}\right) \frac{dx'_h}{d\left(\frac{S}{S_o}\right)} \right] \end{aligned} \quad (4)$$

If zero holdup is assumed, Rose's equation reduces to

$$S = ke^{\lambda} \quad (29)$$

and Colburn's equation reduces to

$$\ln\left(\frac{S_2}{S_1}\right) = \int_{x_{n_2}}^{x_n} \frac{dx_s}{x_D - x_s} \quad (1)$$

Both are forms of the Rayleigh equation.

The operating line equation, upon assuming zero holdup, and substituting  $R = R'/(1-R')$ , reduces to the standard McCabe-Thiele form

$$L'y_n = Lx_{n+1} + Dx_D \quad (30)$$

These equations demonstrate why close agreement is obtained between low-holdup experimental curves and calculated zero-holdup curves.

**Analytical Solution of Differential Equations.** A simplified case was studied in an attempt to determine whether the differential equations could be used in solution. This case involved a column with a still pot and one perfect plate distilling a Henry's law solution. The equations could be solved to yield slowly converging infinite series. Since cases of practical interest would involve more complicated equilibrium relationships and many more plates in a column, it may be concluded that the study of such cases is not warranted.

**Numerical Solution of Differential Equations.** In order to obtain numerical results it has been necessary to ap-

proximate the differential equations, and (c) by the solution of approximate equations, i.e., the finite difference method.

As an example of the first approach, Pigford, Tepe, and Garrahan (5) used the differential analyzer at the University of Pennsylvania to solve batch-distillation problems for a seven-plate column. As is not unusual with a mechanical analog computer, the material balance obtained was not close (a variation of 6%), and the number of equations, i.e., plates, which the analyzer can handle is seriously restricted by the limited number of integrators. This is about ten on the largest analyzer. The machine can, of course, give only numerical solutions; nevertheless, it is fast, and may have advantages in speed that it loses in accuracy.

Under the second case just mentioned, there are many methods given in mathematics texts for obtaining approximate numerical solutions to differential equations. Some of the more familiar are due to Taylor, Picard, Frobenius, Runge-Kutta, Milne, and Simpson. There are, in general, objections to the use of all of these, the primary one being that they are quite laborious. One approximate method of solution considered in this investigation has been by Taylor's Series. O'Brien (3) studied the use of other approximate methods (Euler, Runge-Kutta, and Milne). He concluded that the finite difference method, discussed below, accurately expresses the progress of a distillation.

**Solution of Batch-distillation Equations by Taylor's Series.** The method of simultaneous differential-equation solution by a Taylor's expansion is outlined in Levy and Baggott (2). Since batch-distillation equations may be written in the appropriate forms and meet the requirements of Taylor's theorem, it appears that they may be solved by this method. In order to test this method, calculations were made for the simple case of a column with a stillpot and one theoretical plate distilling a constant-alpha mixture. It was found that close agreement was obtained between distillation curves calculated by Taylor's series and the finite difference method. However, the work was found to be much too time-consuming to be practical. Sources of error were many, errors were cumulative, and the calculations were difficult to check. For these reasons further work with this method was discontinued.

**Derivation of the Finite Difference Equations.** The derivation of the finite difference equations for batch distillation is based on a material balance for a particular component around a particular plate  $n$  of the column during a

approach the problem in one of three ways: (a) by the use of a large analog computer, (b) by the approximate solu-

short but finite period of time. During this time  $\theta$  the plate receives

$$(Lx_{n+1} + Vy_{n-1})\theta$$

moles of the component under consideration and loses

$$(Lx_n + Vy_n)\theta$$

moles of this component. At the beginning of this time interval, the moles of the component held up on the plate are  $H_n x_{n0}$  and at the end  $H_n x_{n1}$ . Since any difference between moles in and moles out must appear as accumulation or depletion on the plate, the following equation may be written:

$$(Vy_{n-1} + Lx_{n+1} - Vy_n - Lx_n)\theta = H_n(x_{n1} - x_{n0}) \quad (41)$$

$$x_{n1} - x_{n0} = \Delta x_n = \frac{\theta}{H_n} [V(y_{n-1} - y_n) + L(x_{n+1} - x_n)] \quad (42)$$

For the simplified case of a column with total condenser, and with negligible condenser and condenser line holdup, so that  $y_t = x_D$ , the following modified equation is obtained for the top plate,  $t$ , if this plate is 100% efficient

$$(Vy_{t-1} + Lx_{t+1} - Vy_t - Lx_t)\theta = H_t(x_{t1} - x_{t0})$$

This reduces to

$$x_{t1} - x_{t0} = \Delta x_t = \frac{\theta}{H_t} [Vy_{t-1} - Lx_t - Dx_D] \quad (43)$$

Analogous equations may be written for each of the other plates. A material balance around the still pot is expressed by the equation

$$S_1 x_{s1} - S_0 x_{s0} = \Delta(Sx_s) = (Lx_1 - Vy_s)\theta \quad (44)$$

By making the substitution  $R = L/D$  and solving for the new composition,  $x_{s1}$ , the equations became

$$\begin{aligned} x_{t1} &= x_{t0} + \frac{\theta D}{H_t} [(R+1)y_{t-1} - Rx_t - x_D] \\ x_{t-11} &= x_{t-10} + \frac{\theta D}{H_{t-1}} [(R+1)(y_{t-2} - y_{t-1}) + R(x_t - x_{t-1})] \\ &\vdots \\ x_{s1} &= x_{s0} + \frac{\theta D}{H_1} [(R+1)(y_2 - y_1) + R(x_2 - x_1)] \\ x_{s1} &= \frac{S_0 x_{s0} + \theta D[Rx_1 - (R+1)y_s]}{S_1} \end{aligned} \quad (45)$$

Repeated use of these equations allows calculation of all the plate and still compositions during an entire distillation, if a set of starting conditions are available. Examples of several such calculations have been indicated in previous papers as follows:

1. Batch distillation when all the usual simplifying assumptions are applicable (7).

2. Batch distillations when all usual simplifying assumptions are applicable except that plate efficiency is not 100% (8).

3. Batch distillation when it is not permissible to assume

- a. Constant relative volatility
- b. Equal heats of vaporization
- c. An adiabatic column
- d. 100% plate efficiency

The second of these previous papers demonstrated that the calculated compositions were in agreement with experimental values. These earlier papers also pointed out the disadvantage of the method; namely, it is very laborious and errors are cumulative. This disadvantage is largely obviated by performance of the calculations on commercially available IBM digital computers. All but the most complicated of the following irregular and nonideal cases can be calculated automatically by this technique.

Only one assumption is inherent in the method. This is that in a short period of time  $\theta$ , referred to as one interval, the compositions of the various streams do not change, or they change in an arbitrarily chosen manner based on general experience or immediate past behavior. This assumption involves an error that may be made as small as desired by decreasing the interval size or determining the rate of change of composition during the interval in a more elaborate manner.

Advantages of the finite difference calculation procedure arise from the freedom of need for simplifying assumptions and restrictions. Thus, if essential, it is possible to make calculations that take into account all the following nonidealities and irregularities, even though they occur simultaneously during a single distillation.

1. Relative volatility is variable.
2. There are unequal heats of vaporization, unequal specific heats, and appreciable heats of mixing of components, resulting in unequal molal overflow.
3. The column is nonadiabatic, also resulting in unequal molal overflow.
4. Plate efficiency is other than 100%.
5. Condenser holdup, or condenser line holdup, is appreciable.
6. Holdup is not uniform on the various plates.
7. Holdup on a given plate changes as the distillation progresses.
8. A partial condenser is used instead of a total condenser.
9. A ternary or multicomponent mixture is distilled.
10. A packed column is used instead of a plate column.
11. Vapor holdup is not negligible.
12. Liquid composition is not uniform across a plate, and not equal to the composition of liquid leaving the plate.
13. A change in the liquid or vapor rate does not affect all plates simultaneously.
14. Reflux ratio is varied during the distillation.

The general approach to these realistic calculations has been indicated in the previously mentioned papers, but will be amplified here. In principle, it is possible to modify the relatively simple Equations (45) so they take into account the various irregularities mentioned. Therefore Equation (57) has been derived for the case where irregularities 2, 3, and 6 are taken into account. However, in general, it is preferable not to derive such complex equations, but to "program" the calculation procedure by listing the order in which the various simpler equations are to be used in obtaining a value of  $x_{s1}$  from  $x_{s0}$ . This is possible because most of the assumptions arise from the repeated use of the basic equations for successive intervals, rather than being inherent in the basic equations as applied to a single interval.

As a result, for example, there is little difference in the basic calculation procedure for cases of variable relative volatility compared with constant relative volatility. In each case before the basic Equations (45) may be used to calculate new liquid compositions at the end of a new interval, it is necessary to use some means of getting the necessary equilibrium vapor compositions at the beginning of the interval, from the known liquid compositions. Where 100% plate efficiency and constant relative volatility may be assumed, the usual relative volatility expression

$$\frac{y}{1-y} = a \frac{x}{1-x}$$

may be used. When relative volatility is not constant, it is almost always possible to express the vapor-liquid equilibrium relation by some functional relation such as

$$y = ax + bx^2 + cx^3 + \dots$$

In many cases it is convenient to use available equations and constants (activity coefficients or  $K$  values) to obtain necessary partial pressures and mole fractions of the equilibrium vapor. In principle it is even possible to use a graph of the vapor-liquid equilibrium data, but this greatly complicates the possibility of machine calculation, and so is not advisable. In any case, the calculation procedure involves alternate use of Equations (45) and some vapor-liquid equilibrium equation or equations, without modification of Equations (45).

When 100% plate efficiency may not be assumed, the procedure is the same, except that after each equilibrium vapor composition is obtained, an equation such as the Murphree  $x$  or  $y$  equations must be used to obtain actual vapor composition from the equilibrium value. Thus, the programming is the repetitive use of the sequence (1) Equations (45), (2) vapor-liquid equilibrium equation, (3) plate-efficiency equation. It is clearly possible to use different plate-efficiency factors for the different plates, and if desired, to go further and take into account the variation of such factors with liquid compositions. This merely introduces into the program sequence a step (2a) calculation of plate efficiency from liquid composition according to some predetermined functional relation.

When there is nonadiabatic operation of the column, the values of  $V$  and  $L$  are different from plate to plate, and may also vary with concentrations in the column. When the latter is not the case, the program of calculation is identical with that previously described, except that the values of  $V$  and  $L$  will be different for each plate, and the proper values must be known and introduced at the beginning of the calculations. Should it be necessary to take into account a change in the magnitude of the heat leak with concentration, a considerably more complicated, but still straightforward procedure is necessary. Thus, a new step (4) would be introduced in which liquid compositions would be used to obtain plate temperature, and this then used (with the temperature of the surroundings and the over-all heat-transfer coefficient) to obtain quantity of heat lost, and finally, the new values of  $V$  and  $L$ .

Inclusion of condenser holdup, condenser line holdup, or use of a partial instead of total condenser, requires modification of the program for the top-plate calculation only, in that the simple relation  $x_D = y_t$  must be replaced by a more complex relation to obtain the correct value for the compositions of the liquid flowing onto the top plate during any interval.

If holdup is different on the different

plates, but remains constant on any one plate throughout the distillation, there is no complication in programming, since it is only necessary to introduce the proper values into the equations for the different plates.

When holdup varies during the distillation, it is probably most frequently because composition changes cause molar volume changes while volumetric holdup remains constant. In this case, a functional relationship  $H = f(x)$  must be established and used to calculate the necessary values for  $H$  for each plate at the beginning of each new interval. However, there are further complications. This change in  $H$  requires a major change in the procedure, because Equations (45) now have three unknowns ( $L_n$ ,  $H_1$ , and  $x_n$ ) instead of just one ( $x_n$ ). Actually  $L_n$  and  $H_1$  are related by over-all material balances, and  $x_n$  and  $H_1$  are also related by  $H = f(x)$  but the latter relation will probably seldom be simple enough to permit explicit solution of (45) for  $x$ . Although no calculations of this type have been made, the best procedure would probably be a trial-and-error iteration as follows: Use  $L_0/H_0$  as a first trial value of  $L_1/H_1$  and follow the normal procedure to obtain a first trial value of  $x_{n1}$ . Use this in  $H = f(x)$  to obtain a second trial value of  $H_1$ , use this in the over-all material-balance equation for the plate to obtain a second trial value of  $L_n$ , and use this in Equations (45) to get a second trial value of  $x_{n1}$ , and so on until successive trials give the same answer. There does not seem to be any way to avoid this major increase in computation load when the change of holdup with time is to be taken into account. The over-all procedure for this case then is (1) Equations (45) iteration as just explained instead of simple use of Equations (45), followed by step (2, 2a) if variation in plate efficiency is to be taken into account, (3) if plate efficiency other than 100% is involved, (4) if operation is nonadiabatic and the heat leak is varying with time during the distillation, plus such steps for the top-plate calculation as are required by the condenser holdup and composition relations. In general, irregular thermal properties such as unequal heats of vaporization and specific heats, and appreciable heats of mixing, result in complexities of the order of those just described for changing holdup. A simple case where only unequal heats of vaporization need be taken into account may be dealt with simply by using fictitious molecular weights. This merely modifies the vapor-liquid equilibrium equation, and the standard program may be used.

A much more complicated case can be dealt with by programming which involves a series of steps. The reasoning

in this case requires a heat balance and an over-all material balance as well as a material balance on more volatile component. A functional relation between enthalpy and composition is also required. The equations are:

$$V_{t-1} + L_R = V_t + L_t \quad (46)$$

$$\begin{aligned} \theta(V_{t-1}y_{t-1} + L_Rx_R) + H_t i_{t0} \\ = \theta(V_ty_t + L_tx_t) + H_t i_{t1} \end{aligned} \quad (47)$$

$$\begin{aligned} \theta(V_{t-1}I_{t-1} + L_Ri_R) + H_t i_{t0} \\ = \theta(V_t I_t + L_t i_t) + H_t i_{t1} \end{aligned} \quad (48)$$

An iterative trial-and-error procedure, similar to that described in the preceding paragraph, may be used. Equation (47) is first used in the regular way to obtain a first trial value of  $x_{t1}$ . This is used to obtain  $i_{t1}$  for Equation (48), from which  $L_t$  is also eliminated by use of (46). Solution of (48) is then easily possible to give a first trial value of  $V_{t-1}$ , and (46) gives the corresponding value of  $L_t$ . These are then used in (47) to get a second trial  $x_{t1}$ , etc. Simpler solution is possible at a sacrifice of some of the rigor of the solution. Thus, if the liquid enthalpy terms or their difference is assumed negligible, (48) reduces to

$$V_{t-1}I_{t-1} = V_t I_t \quad (49)$$

When this and (46) are combined with (47), it may be solved explicitly for  $x_{t1}$  and the standard program may be used. Equation (57) was derived on this basis, and also non-adiabaticity was accounted for by writing (49) as

$$\theta(V_{t-1}I_{t-1}) = \theta(V_t I_t) + Q \quad (50)$$

where  $Q$  is the heat lost. Defining

$$Q = q' \theta(V_{t-1}I_{t-1}) \quad (51)$$

then

$$\begin{aligned} V_{t-1} &= \left( \frac{1}{1-q'} \right) \frac{I_t}{I_{t-1}} V_t \\ &= q \frac{I_t}{I_{t-1}} V_t \end{aligned} \quad (52)$$

Assuming that  $q$  is constant for each plate; i.e., the per cent of heat in the vapor coming to each plate that is lost is the same for all plates in the column, then

$$V_{t-k} = q^k \frac{I_t}{I_{t-k}} V_t \quad (53)$$

Writing equations similar to (46) for all plates to  $(t-k)$ , adding, and substituting (53),

$$L_{t-k} = \left[ \frac{q^{k+1} I_t}{I_{t-(k+1)}} - 1 \right] V_t + L_R \quad (54)$$

Rewriting (47) for plate  $(t-k)$ ,

$$\frac{\theta}{H_{t-k}} \left\{ (V_{t-(k+1)} y_{t-(k+1)} + L_{t-(k+1)} x_{t-(k+1)}) - (V_{t-k} y_{t-k} + L_{t-k} x_{t-k}) \right\} = \Delta x_{t-k} = \quad (55)$$

Substituting (53) and (54) in (55),

$$\Delta x_{t-k} = \frac{\theta}{H_{t-k}} \left\{ \left[ \frac{q^{k+1} I_t}{I_{t-(k+1)}} V_t y_{t-(k+1)} - \frac{q^k I_t}{I_{t-k}} V_t y_{t-k} \right] + \left[ \left( \frac{q^k I_t}{I_{t-k}} - 1 \right) V_t + L_R \right] x_{t-(k+1)} - \left[ \left( \frac{q^{k+1} I_t}{I_{t-(k+1)}} - 1 \right) V_t + L_R \right] x_{t-k} \right\} \quad (56)$$

$$\Delta x_{t-k} = \frac{\theta}{H_{t-k}} \left\{ V_t \left[ \frac{q^{k+1} I_t}{I_{t-(k+1)}} y_{t-(k+1)} - \frac{q^k I_t}{I_{t-k}} y_{t-k} \right] + \frac{q^k I_t}{I_{t-k}} x_{t-(k+1)} - \frac{q^{k+1} I_t}{I_{t-(k+1)}} V_t x_{t-k} \right\} + (L_R - V_t) (x_{t-(k+1)} - x_{t-k}) \quad (57)$$

Multicomponent calculations are relatively simple for cases such as variable relative volatility, plate efficiency, and the simpler cases of holdup and flow variation. In such cases there are as many additional sets of Equations (45) as there are additional components (beyond the binary pair), and an equal number of vapor-liquid equilibrium equations, plate-efficiency equations, etc. Nothing but the basic information and the computational facilities are necessary. Steps in the calculation of the more complicated multicomponent cases have not been considered in detail, so that unexpected complications may develop for these, even though at first sight the procedures for even these seem clear-cut and straightforward extensions of the binary cases.\*

\* Similar statements apply to items 10 through 13 on page 19. Item 14, a change in reflux ratio during the distillation, is a simple matter for any combination of the other items.

Finite difference equations, and methods of using them, are indicated for the successively more complicated cases arising when various combinations of the simplifying assumptions are not applicable. The impossibility of an analogous treatment of the differential equations is mentioned.

It is shown that with adequate computational facilities, it is possible to predict batch-distillation curves for almost any realistic combination of nonideal conditions of practical importance.

## Notation

(See Notation on page 16.)

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## Conclusions

It is shown that the differential equations for batch distillation with appreciable holdup, derived on a plate-by-plate material balance, may be combined to obtain equations identical with those derived from an over-all material balance for the distillation column. Relations to one another of the various forms of equations for the batch-distillation process are indicated.

Results of several approaches toward the solution of the batch-distillation differential equations are described, and it is concluded that these equations are not soluble by any ordinary analytical means. The limitations of analog computers and other numerical solutions are indicated.

Finite difference equations for batch distillation with appreciable holdup are derived. This is done first for the simple case in which all the usual simplifying assumptions of distillation are valid. All these assumptions are listed.

## THE FIRST HUNDRED YEARS (Continued from page 7)

### What Manner of Men

From legendary times until today, no men essential to human progress have kept in better step with the vicissitudes of civilized progress than engineers and their teachers. At the close of World War II college enrollments were decimated—and a few years later their burdens were increased more than tenfold. Yet they have not only survived this torrent of change—they have periodically taken their bearings in the light that history and mastery of their profession gives them—and they have projected

into the uncertain future, plans which have been realistic enough to make engineering a little better, and our standard of living a little higher through periods of prosperity, depression, and war.

History of Engineering Education  
Frederic T. Mavis

### The Engineering Environment

We have now reached the point in the development of engineers where we may expect no percentage increase of engineers in terms of the total population.

Looking Ahead in Engineering Education  
S. C. Hollister

### He Has Worked

When engineering was concerned primarily with laying out railroads, developing mines, and building the physical plant of the country, there was little research activity in industry. A few industrial research laboratories, as we know them today, were in operation in the early 1900's, long after the formation of the first engineering society. Research did not become a significant industrial activity in this country until about the time of the first World War, when engineering turned to the sciences for new frontiers to develop.

Commentary Address  
Clyde Williams

# ABSTRACTS

Abstracts of papers published in "Reaction Kinetics and Transfer Processes," Chemical Engineering Progress Symposium Series No. 4, Vol. 48 (1952). The volume may be ordered from Chemical Engineering Progress, 120 East 41 Street, New York 17, New York.

## HEAT TRANSFER FROM THE WALL OF A TUBE TO A FLUIDIZED BED

Richard N. Bartholomew and Donald L. Katz  
University of Michigan

**H**eat-transfer coefficients to fixed fluidized beds were determined in a steel reactor 4 in. in diam. and 30 in. high. Bed materials consisted of sand, aluminum, and calcium carbonate particles in mixtures of both wide and narrow size ranges, fluidized by air. The heat-transfer data, obtained at wall temperatures of 400° and 600° F., were correlated in terms of four dimensionless groups: the Reynolds number, the Stanton number, the Prandtl number, and the modified drag coefficient.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 3 (1952).

## PARTICLE-TO-FLUID HEAT TRANSFER IN FIXED AND FLUIDIZED BEDS

Jacob Eichhorn and Robert R. White  
University of Michigan

**S**teady-state heat transfer between solid and gas in fixed and fluidized beds is studied as a function of particle size, gas velocity, and gas properties.

These heat-transfer data are in agreement with the  $j$  factors obtained in previous mass-transfer experiments. The fixed-bed pressure-drop data are in agreement with previously published work.

The fluidized-bed heat-transfer work indicates that the solid and gas temperatures for a bed of particles 48/60 mesh and smaller are essentially identical and constant throughout the fluidized system.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 11 (1952).

## HEAT AND MASS TRANSFER IN FIXED-BED REACTORS

R. W. Schuler, V. P. Stallings, and J. M. Smith  
Purdue University

**N**ew experimental conversion-vs.-catalyst-bed-depth data have been obtained for analyzing the design procedures proposed for gas-solid catalytic reactors. The results show that the modified Grossman method, which neglects mass transfer in the radial direction, offers a closer approach to the experimental data than methods which give equal importance to radial mass transfer and heat transfer.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 19 (1952).

## EFFECT OF PRESSURE ON CATALYTIC DEHYDRATION OF BUTANOL-1

J. F. Maurer and C. M. Sliepcevich  
University of Michigan

**T**he effect of pressure on the initial rate of dehydration of butanol-1 over an alumina silica catalyst at 750° F. and at pressures up to 7500 lb./sq.in. gage was determined. It was found that the initial rate of dehydration increased with pressure up to about 2500 lb./sq.in. gage, which corresponds to a fugacity of butanol-1 of 85 atm., and thereafter decreased.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 31 (1952).

## FORMALDEHYDE-SODIUM-PARAPHENOL-SULFONATE CONDENSATION

F. C. Stults, R. W. Moulton, and Joseph L. McCarthy  
University of Washington

**T**he kinetics of the several individual reactions proceeding during the early stages of condensation of the phenol-formaldehyde type of condensation reactions have been investigated.

Since it appears that continuous processing may offer control and cost advantages over the batch methods now common, preliminary experimentation was also conducted to study application of this type of data to prediction of homogeneous polycondensation results obtainable in a continuous-flow tubular reactor.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 38 (1952).

## RATE OF FORMATION OF METHANE FROM CARBON MONOXIDE AND HYDROGEN WITH A NICKEL CATALYST AT ELEVATED PRESSURES

John A. Pursley, Robert R. White,  
and C. M. Sliepcevich  
University of Michigan

**T**he purpose of this investigation was to establish a correlation for the effect of the partial pressures of the reactants on the initial rate of reaction between carbon monoxide and hydrogen to form methane and water,  $\text{CO} + 3\text{H}_2 \rightarrow \text{CH}_4 + \text{H}_2\text{O}$ , on a specific nickel catalyst at elevated pressures.

The range of the investigation was limited to conditions where side reactions and catalyst deactivation could be shown to be negligible.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 51 (1952).

## CATION-EXCHANGE RESIN AS A CATALYST IN THE SYNTHESIS OF ETHYL ACETATE

David J. Saleton and Robert R. White  
University of Michigan

**Q**uantitative-reaction-rate data have been obtained for the formation of ethyl acetate from ethanol and acetic acid in fixed beds of cation-exchange resin catalyst. The complex interaction of diffusion and reaction kinetics within the resin which determines over-all esterification rate has been resolved mathematically. The rate expression finally obtained includes a multiplier function which gives the volumetric efficiency of the resin catalyst. This volumetric efficiency  $\phi$  is shown to be a function of temperature and resin-head size almost exclusively.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 59 (1952).

## RATES OF ALCOHOLYSIS AND DIFFUSION IN ION-EXCHANGE RESINS

George E. Barker and Robert R. White  
University of Michigan

**T**he rate of the reaction of ethanol and *n*-butyl acetate has been determined using fixed beds of cation-exchange resin as a catalyst. The correlation of the data indicates that the chemical reaction and diffusion of the various components within the resin control the rate. The correlation has the form of a second-order chemical kinetics equation multiplied by an efficiency factor, which is primarily a function of temperature and resin-head size.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 75 (1952).

## PRODUCT DISTRIBUTION IN CATALYZED AND UNCATALYZED BATCH HYDRATION OF ETHYLENE OXIDE

P. C. Davis, C. E. Von Waarden,  
and F. Kurata  
University of Kansas

**E**thylene oxide was hydrated in a 2-liter autoclave at 100° to 140° C. and 90 to 120 lb./sq.in. gage to form ethylene glycol and higher glycols. Both caustic and sulfuric acid catalysts were included with uncatalyzed experiments. Caustic was the most active catalyst and had a marked effect upon the distribution of products, increasing the proportion of the higher glycols. Temperature and pressure had no discernible effect upon the product distribution.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes*, **48**, No. 4, 91 (1952).

(More Abstracts on page 25)

# Chemical Engineering

## A New Science

W. K. Lewis Massachusetts Institute of Technology, Cambridge, Massachusetts

THE development of modern chemical industry came in the nineteenth century. Industries such as lime, glass, ceramics, pigments, soap, sugar, fermentation, paper and leather started at far earlier dates. They had developed through empiricism and until relatively recently most of them underwent little improvement. The achievements of the century were creation of new chemical products and discovery of radically new methods for making old ones. This is exemplified in such industries as the acids and alkalies, the synthesis of fuel gases, the manufacture of fertilizers, cement, and new types of explosives, and especially in the development of synthetic organic chemistry, particularly in dyestuffs.

### Solvay Process—A First-Water Achievement

There were engineering giants in chemical industry in those days. Perhaps this fact can best be illustrated by an outline of the development of the Solvay process. The earliest dependable record of recognition of the potentialities of double decomposition of salt with ammonium bicarbonate goes back to 1822, but the work was unpublished. However, there is no doubt that an engineer named Thom, working in a Leblanc plant, was actually making soda by this reaction in 1836, mixing it with Leblanc product and selling it on the market. That its potentialities were fully appreciated is shown by the

fact that during the next two decades four plants attempting to exploit the reaction were built in England and at least five on the continent. All were financial failures. Doubtless one would class them today as pilot plants, but it is beyond question that they were intended to produce for the market. It was twenty-five years after the initial industrial attempt of Thom before the first commercially successful plant was put into operation by Solvay.

Solvay's success was an engineering achievement of the highest order. First, he had to make a reversible reaction go by mass-action effects. In order to do this he had to develop a type of lime kiln that would give high carbon dioxide concentration in the kiln gas. Then, he had to design equipment for the decomposition of solid bicarbonate of soda under conditions that enabled him to recover the dioxide evolved at high yield and relatively undiluted with air. Also, he had to build a pressure reactor for the operation and in this reactor he had to provide for effective countercurrent contact of the gas and liquid. Moreover, he developed this complicated combination of means for securing an adequate mass-action effect six years before the law of mass action was discovered by the chemists, Guldberg and Waage. In addition to all this he had to have independent control of the temperature of the precipitating liquid and its residence time in the reaction zone. The ammonia he put through the

process per cycle cost five times the value of his final finished product, so that he had to develop equipment in which mechanical losses of ammonia were negligible and a process which would recover ammonia in extremely high yield at low cost. These things he did represent superlatively good engineering. Moreover, Solvay, a civil engineer, was not alone in doing this sort of work; despite this fact, chemical engineering as a profession did not come into being in the nineteenth century.

Two important factors delaying the professional development of chemical technology were the type of men in the field and the history of the industry particularly during the last half of the century.

The outstanding leaders in the early development of the mechanical side of the industrial revolution brought to the solution of its problems an engineering point of view which was characteristically modern. James Watt had an analytical mind, dissatisfied with anything short of thorough understanding of the factors fundamental to his problems. Thus, when first faced with the deficiencies of the Newcomen engine, he started a research investigation, setting to work to determine in the laboratory the physical properties of steam. He was the inventor, not only of the steam engine, but also of the indicator, which has been described as the equivalent, for the steam engineer, of the

stethoscope for the physician. Rankine introduced thermodynamic analysis into the field of power generation. In doing so, he was one of the outstanding leaders, along with men like Helmholtz and Clausius, in the interpretation of the new science of thermodynamics. Zeuner in Switzerland was a man of similar type. Under their inspiration mechanical engineering could not fail to acquire professional status. In sharp contradistinction, the leaders in chemical industry, in the early part of the nineteenth century, were predominantly practical men, temperamentally interested in practical results rather than in an analysis of the fundamentals underlying their field of activity.

### Germany in the Lead

The first half of the century developed the heavy chemical industries which are the necessary foundation for any chemical economy. On the other hand, the whole history of applied chemistry during the last half of the century was dominated by the development of synthetic organic chemistry, based on the discovery of mauve by Perkin. The development and manufacture of the new dyestuffs offered fascinating opportunities, but it was Germany that was in a unique position to take advantage of them. The industry required large numbers of well-trained organic chemists. Universities of Germany, unlike those of England, had for decades fostered chemistry as a science and German industry was quick to exploit the advantages of the situation. Long before the end of the century, Germany was supreme in the whole field of synthetic organic manufacture.

On the other hand, the very extent of the German success deflected professional development in the wrong direction. The manufacture of dyestuffs was predominantly a set of small-scale operations, the equipment for which was blown-up laboratory apparatus, enlarged in dimensions. Similarly, the process was the batch operation of the laboratory. Control was in the hands of chemists, using the laboratory worker's viewpoint.

The chemists turned out by the German universities were superlatively trained for these tasks. Details of construction were left to mechanical engineers, but these designers were implementing the ideas of the chemists, with little or no understanding of the underlying reasons for specific performance. The result was a divorce of chemical and engineering personnel, not only in German technical industry, but also in the universities and engineering schools that supplied that industry with professionally trained men.

The technical developments of the

end of the century created a new situation out of which finally grew chemical engineering as we know it today. Around 1880, the invention of the dynamo for the first time made available to industry cheap, direct-current electric power. It is difficult for the modern imagination to grasp the impact which the potential use of this new form of energy made upon technical men in the chemical field. For more than a half century, chemists had spent an extraordinary amount of energy on the perfection of primary batteries, because in those days these were the only practical source of low voltage, high amperage, direct current. Moreover, despite the inherent limitations of the primary cell, the success achieved had been remarkable. The men who did this work recognized full well the economic possibilities of electrochemical decomposition, once cheap power was available, and they looked forward enthusiastically to the rapid development of a new industrial era. To appreciate the intensity of effort in the electrochemical field in the years immediately following, one need only mention the work on electrolysis of salt of Le Sueur in 1892, Castner in 1893, Hargreaves-Bird in 1894, and Carmichael in 1896. The production of aluminum by Hall and Héroult came even earlier, in the eighties. In the electrothermal field, the manufacture of carborundum by Acheson was achieved in 1891 and of carbide by Wilson in 1895. The early work of Bradley and Lovejoy (1902) on arc fixation of nitrogen was followed by the developments of Birkeland and Eyde (1904) and of Schoenherr in 1908.

### Beginnings of Mass Production

The character of these electrochemical innovations foreshadowed a new emphasis in chemical industry, weighted heavily on the engineering side. Of even greater importance, as it turned out, was the trend toward mass production, with the concomitant increase in output and decrease in cost. The situation as it existed is most easily understood from a specific illustration. Fuming sulfuric acid had long been made by the distillation of ferric sulfate formed by the weathering of pyritic shales (Nordhausen acid). Even as late as 1880, this was a major source, fifty per cent oleum costing eight cents a pound. The sulfate was distilled in small earthenware flasks containing batches of less than two pounds each. As long as oleum was only a laboratory chemical, this was not serious, but when it became necessary to use it for such purposes as the oxidation of naphthalene in the synthesis of indigo the situation became intolerable. The development of the contact process, one of the early

outstanding achievements of modern chemical engineering, was the result.

The tides of industrial expansion moved inexorably to sweep the leadership out of the hands of Germany. The development of hydroelectric power at Niagara made available far larger supplies of energy than the market could absorb for conventional uses. Power companies were therefore constrained to offer their product for electrochemical consumption. This necessitated large-scale, low-cost, long-term contracts. Thus, a group of great electrochemical industries concentrated in the area and expanded with extraordinary rapidity.

As already mentioned, however, it was the trend toward mass production that was the greatest factor in the development of chemical engineering. In Germany, labor was cheap—from the trained chemist down to the common workman. In America, both chemist and workman were expensive. The costly laborsaving device which the American manufacturer could not afford *not* to use, his German competitor could not afford even to consider. Forty-five years ago, as a student in one of the great industrial cities of Germany, this author saw the piling for the foundations of a new, large, modern business building driven by workmen on the ends of a cat-o'-nine-tails; in this country, I had never seen such work done other than by a donkey engine, even on construction in backwoods areas. America had to keep costs down by every practicable device to increase the efficiency and effectiveness of human labor. Mass production was the solution of the problem.

### Consider Explosives

The way things worked out is well illustrated by the explosives industry. Explosives are laborsaving devices. Their use lessens the amount of human toil required in mining and construction, and, where labor is dear, lowers costs. Their consumption expanded rapidly in this country in the last half of the century. This in turn made possible an enlarged scale of production, with its corresponding savings and lowering of costs. As a result of this cycle of increasing efficiency, before the outbreak of World War I the production of explosives in this country had grown to the point where it was some four-fold that of Germany. In contrast, in the manufacture of dyestuffs, where the output of a given product was small and each operation had to be supervised by a skilled organic chemist, Germany was supreme and America could not compete.

The sort of technical leadership required by this new era in chemical in-

dustry demanded the creation of a new profession. The first recognition of the need came in England, in the attempt to establish a "Society of Chemical Engineers" in London, in 1880. The project was abandoned because it was felt that the potential membership was too limited. On the other hand, that the sponsors knew what they were driving at is clear from the definition of the chemical engineer stated at the time as "a person possessing a knowledge of chemistry, physics, and mechanics and who employed that knowledge for the utilisation of chemical reactions on the large scale."

### A Need for Education

The first truly constructive step toward the establishment of the new profession came in the recognition that the problem was primarily one of education. The credit for this belongs to George E. Davis, who, in 1887, gave the first course of lectures on Chemical Engineering in the Manchester Technical School. These formed the basis for his two-volume "Handbook of Chemical Engineering," published in Manchester, in 1901. He points out that "to produce a competent Chemical Engineer the knowledge of chemistry, engineering, and physics must be co-equal." He recognizes the existence and importance of unit operations, although not using that term to describe them. He outlines and illustrates the method of the large-scale laboratory experiment as a first step in the evaluation of a proposed new process. He emphasizes the importance of mass-action effects, not only upon reaction equilibrium, but also upon reaction rate and equipment capacity. He classifies the reactions of chemical industry as to type. Few indeed are the really fundamental phases of chemical engineering to which he does not call attention. Unfortunately, his quantitative treatment of operations is limited by lack of data and the decidedly incomplete development of professional knowledge at the time. This in nowise detracts from the credit due his pioneering initiative.

### William Walker—Progenitor of Chemical Engineering Curricula

In view of the situation resulting from the expansion of electrochemistry and mass production in America at the turn of the century and the insistent demand for a new type of technical leadership which it created, it is not surprising that the first effective step toward furnishing a sound, broad educational training for the new profession came on this side of the water. It was taken by William H. Walker at the Massachusetts Institute of Technology. He came to its faculty in 1902 to de-

velop its curriculum in chemical engineering. He recognized the importance of basic training in chemistry and especially the value of the new discipline in physical chemistry. He understood the necessity for thorough grounding in the techniques of engineering and in the difficult art of applying the sciences to the solution of practical problems. On this basis he introduced the curriculum for the training of men for the new profession; in essentials, it is the curriculum found universally in American schools today.

Walker also appreciated the importance of research in industry and the value of education by doing. He met this phase of the problem by the organization in 1906 of what two years later became the Institute's Research Laboratory of Applied Chemistry, for the training of the student through work on problems of industrial research, conducted cooperatively with industry itself. A few years later he organized the Institute's School of Chemical Engineering Practice, which had been established through the efforts of Arthur D. Little. Here the student was given in the plant the engineering equivalent of the hospital internship for the young medical graduate.

The new profession got its trial by fire in World War I. American chemical industry had to expand to an extraordinary degree, not only to meet the demands made upon it by the military requirements of England and France and, later, the United States, but also to satisfy the world markets hitherto supplied by European industry. The achievement accomplished perhaps can best be illustrated by Edgewood Arsenal—a plant built under war conditions from the ground up for the synthesis of toxic gases, manufacturing new products by processes that were likewise almost wholly new. Parenthetically, this plant was built and put into successful operation by the same Walker who, by his contributions to education, had started the chemical engineering profession on its way.

The war put American chemical industry firmly on its feet. In the profession it infused a self-confidence without which the progress of the industry in the succeeding decades would have been impossible. However, the climax of achievement came in the chemical developments of World War II. At the end of that struggle, not America alone, but the rest of the world as well, realized that in the chemical engineering profession there was indeed something new under the sun.

This paper was presented at the Centennial of Engineering, Chicago, Ill., as part of the Symposium Program, Section VIII—Chemical Industries, held Sept. 9, 1952.

## ABSTRACTS

(Continued from page 22)

### KINETICS OF UNCATALYZED VAPOR-PHASE HYDRATION OF ETHYLENE OXIDE

M. D. Straube and F. Kurata  
University of Kansas

The experimental results are given of a preliminary kinetic study of the uncatalyzed vapor-phase hydration of ethylene oxide to form ethylene glycol. The reaction was carried out under single-pass flow conditions over a temperature range of 300° to 400° F. under a pressure of 30 lb./sq.in.abs. A single mole ratio of steam to ethylene oxide of approximately 5:1 was used throughout this study. The maximum conversion was limited to about 2% of the ethylene oxide feed to avoid the formation of higher glycols. Although the order of the reaction could not be definitely established, the results of this investigation appeared to be consistent with those of the liquid-phase reaction.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes,* **48**, No. 4, 98 (1952).

### CATALYTIC OXIDATION OF NITRIC OXIDE ON SILICA GEL

R. W. Baker, H. N. Wong, and  
O. A. Hougen  
University of Wisconsin

The oxidation of nitric oxide is unique in that the rate of the forward reaction diminishes with increase in temperature for the uncatalyzed gaseous reaction. In this investigation a similar temperature effect was found for the reaction catalyzed by silica gel. Of twenty or more postulated mechanisms, it was found that one was rate controlling, namely, the surface reaction between the complex nitric oxide ( $\text{NO}_x$ ) with unadsorbed oxygen. Rate equations were established based upon unit mass of catalyst over the range of commercial interest.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes,* **48**, No. 4, 103 (1952).

### CATALYTIC OXIDATION OF NITRIC OXIDE ON ACTIVATED CARBON

M. N. Rao and O. A. Hougen  
University of Wisconsin

The homogeneous oxidation of nitric oxide to nitrogen dioxide in the gaseous phase is slow, especially at low concentrations (1 to 3%). The possibility of using activated carbon as a catalyst was investigated by means of a series-type flow reactor, and a rate equation to represent the plausible mechanism of this catalytic oxidation is offered. A comparison of the homogeneous reaction with the catalytic reaction using silica gel and activated carbon as catalysts is made in terms of reaction rates and reactor volumes.

*Chem. Eng. Progress Symposium Series—Reaction Kinetics and Transfer Processes,* **48**, No. 4, 110 (1952).

**I**N RECENT years continuous chemical processing has become firmly established as the assembly-line technique of the chemical-process industries. The adaptation of continuous operations in place of the time-honored batch methods has been advantageous especially in operations where uniformity of product, reduced labor costs, the elimination of dead times (e.g., charging and discharging, heating-up and cooling-down times), and enhanced plant and labor productivity have resulted in a pronounced decrease in the cost of production. However, continuous operations may not always result in decreased production costs, as a consequence of the decreased over-all reaction rate inherent in a continuous-reactor system.

With chemical industry today straining to meet peak production demands in the face of rising costs, the conversion from batch to continuous processing may provide the single solution to this dual problem. It is important to recognize that it is from batch-reaction data that the continuous system most often is designed. Often, only minor alterations in equipment, piping, and valving can mechanically implement the conversion. The resulting system, too, can provide for either batch or continuous operation, with batch operation reserved for start-up and emergency operations. In an over-all sense the conversion from batch to continuous operation is the logical next step, with the batch data and equipment providing the necessary groundwork.

### The Problem

Pilot-plant batch data are most useful for the design of economically optimum commercial continuous-reactor systems. With the pilot-plant batch reactor there can be accumulated the reaction velocity, heat transfer, and mixing data necessary. The scale-up may then be straightforward if the role of the mixing equipment is properly taken into account. The mixing equipment affects the flow patterns and level of dispersion of the reactants and hence reaction kinetics and heat transfer. It also affects the short-circuiting of the reactants in the continuous reactor from inlet to outlet.

In Figure 1 a typical liquid-phase continuous-reactor-vessel system is shown. The vessels are series connected so that the effluent from the first reactor is the feed to the second, the effluent from the second reactor is the feed to the third, etc. Other more complicated arrangements-forming series and parallel circuits might be used. Mixers are fitted into each reactor, and the vessels are jacketed for heat transfer. The effective use of batch data de-

# The Design of Commercial Continuous-Reactor Systems

From Pilot-Plant Batch Data

A. P. Weber

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mands that the following design premises for continuous operation exist:

1. The mixing in each reactor is such that essentially homogeneous mixing obtains or no concentration gradient exists.
2. The reactant concentrations in the exit stream from each reactor are identical with the concentrations in the reactor.
3. The reactant throughput rates and concentrations are constant over the period during reaction.
4. The reaction rates in the continuous-reaction system will be the same as for the batch-reaction system when the concentration of the reactants is the same in both systems at the same point in the reaction. This assumption is not true where simultaneous or side, or irreversible reactions are involved.
5. The reaction-velocity curve does not pass through a maximum or minimum during the course of the reaction.
6. The concentrations of the reactants are additive with respect to volume, i.e.,  $\bar{C} = \Sigma CV/\Sigma V$ .

These design premises either expressed or implied, in whole or in part, have formed the foundation for past investigations (1-14) of the theory of continuous liquid-phase mixed-tank reactor systems. The mixing system employed in the reactor sequence either establishes or destroys the validity of these underlying assumptions. Chemical engineering design theory, like reaction kinetics and heat transfer, is dependent upon an understanding of the role played by the mixing equipment. The use of pilot-plant batch data therefore must include proper analysis of the mixing system. Both a conversion and a scale-up problem are involved. The elements of the problem involve reaction kinetics, economics, short-circuiting, and heat transfer. The liquid-phase matrix in which these problem elements are resolved exerts its influence through the mixing or flow patterns obtaining.

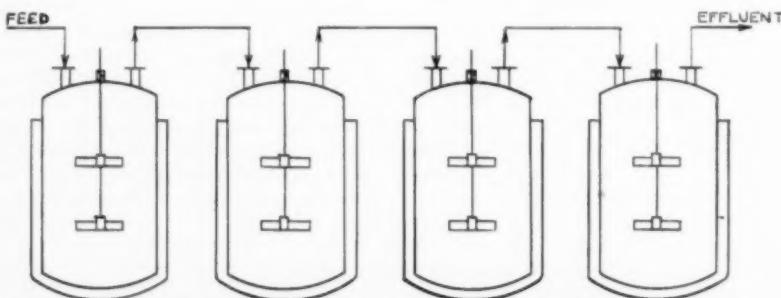


FIG. 1. Continuous Mixer-Reactors Operating in Series.

## Reaction Kinetics

In batch reactors or tubular-type continuous reactors, the well-known kinetic rate equations are applicable but do not adequately define the material balance that obtains in a continuous-stage-reaction system. In these systems the primary reactant is being continuously removed by the reaction process as well as by the effluent stream from the reactor. Simultaneously the reactant is being continuously replenished by the feed stream to the reactor. At the steady state the partial rates of gain and loss of reactant are balanced, so that the net change in reactant concentration in each vessel is zero; that is

$$\begin{aligned} \frac{dC_{a_i}}{dt} &= 0 = \frac{(\partial C_{a_{i-1}})}{\partial t} \text{ influent} \\ &\quad - \frac{(\partial C_{a_i})}{\partial t} \text{ effluent} \\ &\quad - \frac{(\partial C_{a_i})}{\partial t} \text{ reaction.} \end{aligned} \quad (1)$$

The influent and effluent partial derivatives can be evaluated readily by considering the concentration change over a time interval  $\Delta t$  and then forming the derivatives:

$$\frac{C_{a_{i-1}}F}{V} - \frac{C_{a_i}F}{V} - \frac{(\partial C_{a_i})}{\partial t} = 0 \quad (2)$$

where

$C_{a_{i-1}}$  = feed concentration to reactor  $i$   
 $C_{a_i}$  = reactant concentration in reactor  $i - 1$

$C_{a_i}$  = reactant concentration in reactor  $i$

$F$  = volumetric throughput rate

$V$  = volume of a reactor, all reactors assumed as having equal volume

The partial derivative which accommodates the reaction in this continuous system is identical with that in a batchwise system and for convenience can be defined as  $K$ ; that is, for the reaction



the kinetic equation is

$$\frac{(\partial C_{a_i})}{\partial t} = -K = -kC_A^a C_B^b C_D^d. \quad (4)$$

It is not essential to know the analytic expression for this partial derivative, since a batchwise experimental determination of  $C_A$  vs.  $K$  provides sufficient data to complete the design of the system, using a graphical method. It should be kept in mind that Equation (3) does

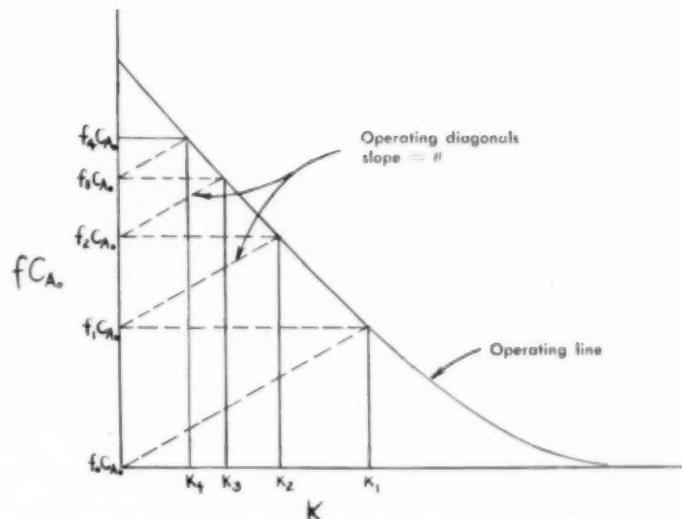


FIG. 2. Graphical Solution of Design Equation (10) for a Four Vessel System.

not necessarily represent a stoichiometric-reaction equation, but instead is used to define the mechanism of the rate-limiting step in a series of individual consecutive reactions.

The reactor volume  $V$  divided by the volumetric throughput rate  $F$  defines a quantity  $\theta = V/F$  having the units of time, and this quantity represents the nominal or average holding time during which the reactant remains in the reactor. The substitution of these definitions and a rearrangement of Equation (2) gives a difference equation of the form

$$\theta = \frac{C_{a_{i-1}} - C_{a_i}}{K_i}. \quad (5)$$

To solve this difference equation, we shall consider the first vessel of the series, since its feed concentration of primary reactant is known to be  $C_{a_0}$ . We shall now let  $f_1$  = the fraction of  $C_{a_0}$  which is converted to product in vessel 1. Hence,

$$C_{a_1} = (1 - f_1)C_{a_0}. \quad (6)$$

Substituting (6) into (5) gives:

$$\theta = \frac{C_{a_0} - (C_{a_0} - f_1 C_{a_0})}{K_1} = \frac{f_1 C_{a_0}}{K_1}. \quad (7)$$

The quantity  $f_2$  is now defined as the fraction of the original primary reactant concentration  $C_{a_0}$ , which is converted to product in a two-vessel continuous-stage-reaction system. Hence,

$$C_{a_2} = (1 - f_2)C_{a_0}. \quad (8)$$

Substituting (8) and (6) into (5) gives:

$$\begin{aligned} \theta &= \frac{(1 - f_1)C_{a_0} - (1 - f_2)C_{a_0}}{K_2} \\ &= \frac{(f_2 - f_1)C_{a_0}}{K_2}. \end{aligned} \quad (9)$$

In like manner it can be shown that the expression

$$\begin{aligned} \theta &= \frac{f_1 C_{a_0}}{K_1} = \frac{(f_2 - f_1)C_{a_0}}{K_2} \\ &= \frac{(f_3 - f_2)C_{a_0}}{K_3} = \frac{(f_4 - f_3)C_{a_0}}{K_4} \\ &= \frac{(f_n - f_{n-1})C_{a_0}}{K_n} \end{aligned} \quad (10)$$

is valid for a multivessel system, and therefore a graphical solution is allowable for the number of vessels required to attain a conversion  $f_n$ , using only batchwise reaction data to establish an empirical curve of  $fC_{a_i}$  vs.  $K$ . Subscripts 1, 2, 3, 4, . . . ,  $n$ , refer to vessels 1, 2, 3, 4, . . . ,  $n$  in a continuous-reactor series; subscript 0 refers to the feed to the first reactor in the series.

Figure 2 represents the graphical relationship between the hold-up time or nominal holding time per reactor  $\theta$ , the incremental fractional degree of completion per reactor, and the number of reactors needed in series for an over-all degree of completion  $f_n$ , under the reacting conditions established in the pilot batch reactors.

The graphical procedure for the selection of any system is as follows:

1. From pilot-plant batch-reactor data the curve  $fC_{a_i}$  vs.  $K$  must be established.
2. The desired nominal holding times of the vessels must be chosen, in order

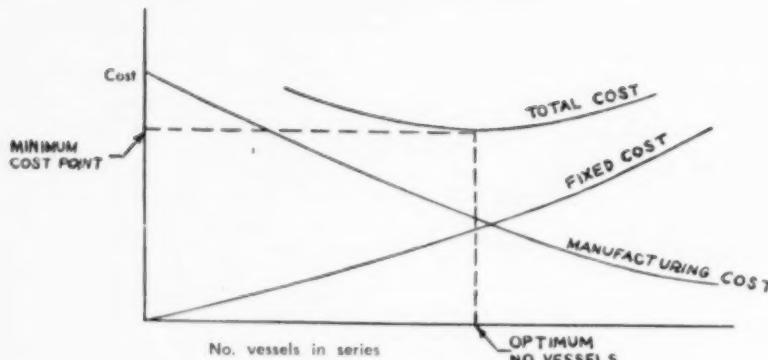


FIG. 3. Graphical Solution For Optimum Reactor System.

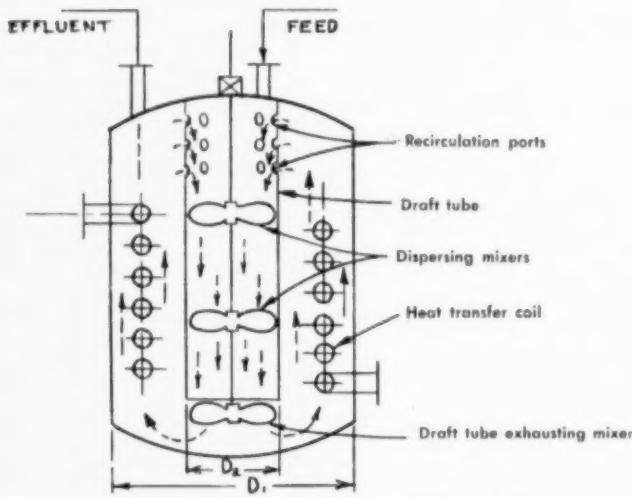


FIG. 4. Typical Continuous Reactor.

to establish the slope of the operating diagonal.

3. Starting from the origin, a line is drawn with slope  $\theta$  until it intersects the  $f_n C_{e_0}$  vs.  $K$  operating line.
4. The ordinate at this point represents the prevailing concentration in the first reactor, which is also the feed concentration to the second reactor. Construct a horizontal line from the operating line so as to return to the  $f_n C_{e_0}$  axis, when  $K = 0$ .
5. Again construct a line with slope  $\theta$ , starting from the point ( $K = 0$ ,  $f_n C_{e_0} = f_1 C_{e_0}$ ) until the operating line is again intersected.
6. Continue this process until the operating line is intersected at a point above  $f_n C_{e_0}$ , which is the minimum degree of conversion desired from the system.
7. The number of diagonals establishes the number of reactor vessels required, operating at a nominal holding time of  $\theta$ .
8. The throughput rate  $F$  will be established by the desired production capacity,  $f_n C_{e_0} F$ , and the throughput rate in turn will establish the reactor volumes  $V$  through the nominal-holding-time relationship  $\theta = V/F$ .

In the foregoing analysis, there is no

inherent limitation requiring that all vessels have identical volumes. If a heat-transfer problem arises, for instance, such that sufficient cooling surface is difficult to realize, smaller reactors can be used in some reacting ranges. The only modification needed is to adjust the slope of the operating diagonal to the correct value for each individual vessel in the series.

This method can be used also to calculate the production capacity which would be realized by connecting existing batch systems to continuous-stage-reaction systems. However, before any design is frozen, this design process should be repeated using several values of  $\theta$  in order to establish the economically optimum system. This will be considered more fully in the next section.

### Economics

The advantages to be gained from a continuously reacting system can accrue whether a single- or multivessel system is used. As the number of vessels used

in a reactor series is increased, however, benefit can be derived from the increased reaction velocity in each vessel resulting from the reduced fractional completion of reaction specified for each vessel. Thus, as the number of reactors in series is increased, the total volume of the series system is decreased. As an infinite number of vessels in series is approached, the continuous system reverts to the minimum-volume-batch system. An economically optimum system is clearly indicated. As the number of vessels in series increases, the fixed charges (amortization, interest, maintenance and repair costs, taxes, insurance, etc.) will increase because of the increased investment; and the manufacturing charges (inventory and utilities costs) will decrease owing to the decreased processing time.

The curves shown in Figure 3 can be plotted for several systems established from the previously given graphical technique (Fig. 2). Head-room and floor-space limitations, the availability of equipment, and other such special limitations may exert a strong influence in spite of the indicated economic optimum.

### Short-circuiting

For the condition of continuous feed and continuous discharge, there does not exist any means whereby a uniform retention time within the reactor vessel for all portions of the feed is assured. The effluent from the reactor vessel will be made up of portions which had stayed for various periods of time in the system. Yet, the degree of completion of reaction does vary as a function of the time spent in the system. Because such is the case, the scale-up and conversion from pilot-plant batch data to commercial continuous reactors should take cognizance of the short-circuiting problem. To resolve the problem there must be obtained some quantitative picture of the effluent composition from the continuous reactor in terms of the retention times in the system.

To develop the quantitative picture, a draft-tube-and-mixer assembly may be employed (Fig. 4), in which well-baffled mixed-tank reactors and other constructions which mechanically impede short-circuiting are used. The typical construction in Figure 4 was chosen because of its ready adaptability to analysis. Other specific arrangements may be more advantageously suited to specific processing demands.

The draft tube in Figure 4, by defining the average course which any portion of the feed will travel from inlet to outlet nozzle, restricts to an approximate predictable value the residence

time of any portion of the feed in the reactor vessel. The draft tube also serves to restrict the path of the incoming stream so that new feed is subjected to the intensive mixing action existing in the vicinity of the mixing elements. The recirculation ports in the draft tube permit a recycling of a portion of the mix previously discharged from the draft tube back through the mixers. The draft-tube exhausting mixer creates a constant turnover in the reactor vessel by functioning as a caseless pump.

Using the reactor vessel of Figure 4, the short-circuiting, or time proportion, of the discharge can be evaluated. If  $F$  is the volumetric throughput rate for the reactor system and  $Q$  is the recirculation rate of the draft-tube exhausting mixer, then the proportion of the discharge comprising feed having made only one pass from the inlet to outlet nozzle will be  $F/Q$ . It is to be noted here that in all cases of practical design  $F$  is substantially lower than  $Q$ .

Let

$$p = F/Q. \quad (11)$$

Let

$$q = 1 - p. \quad (12)$$

The proportion of material remaining in the vessel after one pass will be  $q$ ; and hence the proportion of the feed material leaving on the second pass will be  $pq$ . Similarly, the proportion of the feed remaining after two passes will be  $q - pq = q^2$ , the proportion leaving on the third pass will be  $pq^2$ , and so on to  $pq^{n-1}$  for  $n$  passes (see Table 1).

If two identical reactors are operated in series, the shortest time of stay of feed material in the two-vessel system will be two passes, one pass in the first reactor and one pass in the second. Of the proportion  $p$  of one-pass material leaving the first reactor, a proportion  $(p)(p) = p^2$  will be discharged from the second reactor. There are two ways in which material can leave the two-reactor system after three passes: by making one pass in the first reactor and two passes in the second or two passes in the first reactor and one in the second. Formulating these combinations, then,  $p(pq) + pq(p) = 2p^2q$  will be the total proportion of material leaving the two-reactor system after a stay of three passes.

There are three ways in which material can leave the two-reactor system after four passes: by making one pass in the first and three in the second or two passes in the first and two in the second or three passes in the first and one in the second. Formulating these combinations, then,  $p(pq^2) + pq(pq) + pq^2(p) = 3p^2q^2$  will be the total proportion of material leaving the two-reactor system after a stay of four passes.

Continuing with the two-reactor system for five, six, and subsequent passes, the proportion leaving the second vessel after  $n$  passes can be shown to be  $c p^n q^{n-1}$ , where  $c = (n-1)!/(n-2)!$  (see Table 1).

An identical approach can be used for a three-reactor system. The shortest time of stay in the three-reactor system must be

TABLE 1.—PROPORTIONS OF FEED BY-PASSING IN EFFLUENT FROM CONTINUOUS MIXED-TANK REACTOR SERIES

Number of vessels in series	Total number of passes in the reactor system								
	1	2	3	4	5	6	7	8	$n$
1	$p$	$pq$	$p^2q^2$	$p^3q^3$	$p^4q^4$	$p^5q^5$	$p^6q^6$	$p^7q^7$	$p^{n-1}q^{n-1}$
2	$\vdots$	$p^2$	$p^3$	$p^4$	$p^5$	$p^6$	$p^7$	$p^8$	$C p^n q^{n-2}$
3	$\vdots$	$\vdots$	$p^3$	$p^4$	$p^5$	$p^6$	$p^7$	$p^8$	$C^2 p^n q^{n-3}$

$p^3$ , since the proportion  $p^3$  leaving the first two reactors in the series is discharged from the third after staying one pass in that reactor. For four passes there are three possible combinations wherein material may contrive to stay in a three-reactor system, and when set down and added together the total proportion leaving the third vessel will be  $6p^3q^2$ . Applying the same analysis to all other retentions, five passes, six passes, and so on to  $n$  passes, the proportion leaving can be shown to be  $C p^n q^{n-3}$ , where  $C = (n-1)!/(2(n-3)!$  (see Table 1).

Proceeding as above for a one-, two-, or three-reactor system, the argument can be developed for the general case of  $m$  reactors in series. The proportion (i.e., short-circuiting) of feed materials leaving a continuous-reactor system of  $m$  vessels in series after a retention of  $n$  passes is a function of  $m$ ,  $n$ ,  $F$ , and  $Q$  and can be written

$$\frac{(n-1)!}{(m-1)!(n-m)!} p^m q^{n-m} \quad (13)$$

for all values of  $m$  from 1 to  $\infty$  and all values of  $n$  from  $m$  to  $\infty$ . For example, in the case of three reactors and five passes, as previously noted, the proportion of feed by-passing to the effluent from the third reactor will be seen from Equation (13) to be  $(4 \times 3 \times 2 \times 1)/(2 \times 1)(2 \times 1)p^3q^2 = 6p^3q^2$ .

Since the sum of all proportions by-passing to the discharge from the reactor series must equal 1, one may write

$$\sum_{n=m}^{\infty} \frac{(n-1)!}{(m-1)!(n-m)!} p^m q^{n-m} = 1 \quad (14)$$

The mathematical validity of Equation (14) can be proved as follows. Instead of by-passes or, conversely, retentions being evaluated in terms of the number of passes made by feed material, the various retentions may be evaluated in terms of time measurement. The time  $\delta$  required for a single pass from inlet to outlet, in a continuous reactor having a total working capacity  $V$ , will be

$$\delta = \frac{V}{Q} \quad (15)$$

All other stays or retentions in the reactor system would then take the form of  $n\delta$ , where  $n$  is the number of passes achieved. The average time spent by feed material in the system will be the sum of all retention proportions multi-

plied by the time of stay for each proportion. When the average retention time in the system is  $\theta$ , one may write

$$\theta = \sum_{n=m}^{\infty} \frac{(n-1)!}{(m-1)!(n-m)!} p^m q^{n-m} \cdot n\delta \quad (16)$$

or

$$\theta = p^m \delta \sum_{n=m}^{\infty} \frac{(n-1)!}{(m-1)!(n-m)!} q^{n-m} \quad (17)$$

Expanding,

$$\begin{aligned} \theta = p^m \delta & \left[ \frac{(m-1)!m}{(m-1)!(n-m)!} q^0 \right. \\ & + \frac{m!(m+1)}{(m-1)!(1)!} q^1 \\ & + \frac{(m+1)!(m+2)!}{(m-1)!(2)!} q^2 \\ & + \dots \left. \right] \end{aligned} \quad (18)$$

$$\begin{aligned} &= p^m \delta \left[ \frac{m}{0} + \frac{(m+1)m}{1} q \right. \\ & + \frac{(m+2)(m+1)m}{2} q^2 + \dots \left. \right] \end{aligned} \quad (19)$$

$$\begin{aligned} &= p^m \delta m \left[ 1 + \frac{(m+1)}{1} q \right. \\ & + \frac{(m+2)(m+1)}{2} q^2 + \dots \left. \right] \end{aligned} \quad (20)$$

The terms in brackets represent a converging infinite series whose summation value is  $1/(1-q)^{m+1}$ . Therefore, Equation (20) may be written as

$$\theta = \frac{p^m \delta m}{(1-q)^{m+1}}. \quad (21)$$

Since from Equation (12)  $q = 1-p$ , Equation (21) may be rewritten as

$$\theta = \frac{p^m \delta m}{[1-(1-p)]^{m+1}} = \frac{p^m \delta m}{p^{m+1}} \quad (22)$$

or, dividing numerator and denominator by  $p^m$ ,

$$\theta = \frac{m\delta}{p}. \quad (23)$$

But from Equation (15),  $\delta = V/Q$ ; and, from Equation (11),  $\rho = F/Q$ . Hence, Equation (23) may be written:

$$\theta = \frac{mV/Q}{F/Q} \quad (24)$$

or

$$\theta = \frac{mV}{F} \quad (25)$$

Equation (25) is axiomatic in its mathematical statement that the average hold-up time in a continuous-reactor series is equal to the number of reactors in the series times the volume per reactor, all divided by the volumetric throughput rate. Thus, by the reduction of Equation (14) to Equation (25), the validity of Equation (14) has been proved.

Essentially, Equation (14) establishes the importance of the in-vessel recirculation rate  $Q$ , relative to the throughput rate,  $F$ . If the pilot-plant reactor were a continuous-type reactor, Equation (14) would establish, further, that in scaling up to a commercial-sized continuous reactor the ratio  $F/Q$ , should be preserved. However, in the pilot-plant batch reactor, measurement of  $F$  cannot be made. On the other hand, the recirculation rate  $Q$  can be established from pump theory (Fig. 5), and the reaction volume  $V$  is also known. The number of passes or recycles per unit time,  $N_t$ , occurring in either the batch or continuous reactor, will be:

$$N_t = \frac{Q}{v}. \quad (26)$$

The recycle rate, Equation (26), directly sets the rate at which the contents of the batch or continuous reactor is subjected to the work of the dispersing mixers inside the draft tube. The ratio  $Q/V$  should be preserved or perhaps improved in going from the pilot-plant batch to commercial-plant continuous reactor if the mixing action, likewise, is to be preserved or improved.

The recycle rate and resulting level of dispersion provide for an indirect measure of the short-circuiting. The better the dispersion, the more nearly will the reactant concentrations in the exit stream be identical with the concentrations in the reactor and the deleterious effects of short-circuiting be minimized.

### Heat Transfer

Heat transfer to maintain reaction temperature may or may not exist as part of the design problem. Either heating or cooling may be involved. The heat-transfer means may take the form of coils, jacketed surfaces, electrical re-

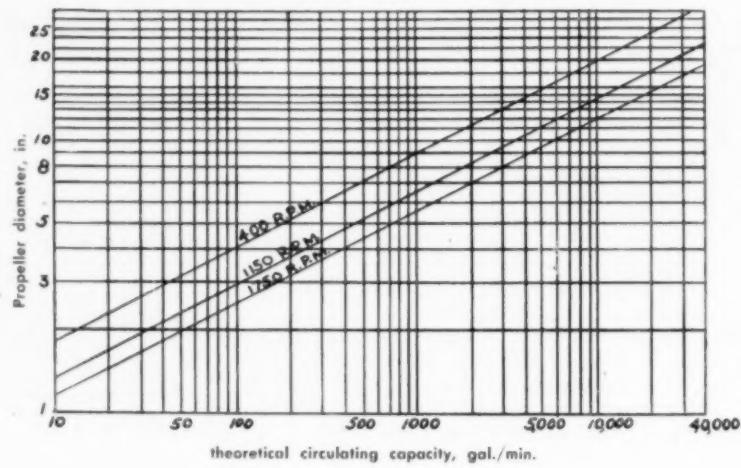


FIG. 5. Propeller Mixer Pumping Capacity.  
(where diameter = pitch)

sistance elements, or direct firing. Adequate coverage of the scale-up problem for all the conceivable cases of heat transfer clearly is beyond the intended scope of this paper. However, some general remarks pertinent to this discussion seem to be in order.

Heat transfer in liquid-phase stirred-tank reactors implies heating or cooling principally by convection. The transfer of heat by convection involves the mixing or mass transfer of those streams which are or have been in direct contact with the heat-transfer surface with contiguous portions of the reactor contents. The effectiveness of the mixing action will in most cases determine the magnitude of the over-all coefficient of heat transfer and hence determine the rate of heating or cooling.

Advantage can be taken of the mixer and draft-tube arrangement of Figure 4 to produce a forced drift of liquid past a coil bank or jacketed vessel shell to improve the heat-transfer rate and give sharper definition to the problem. For scale-up purposes from the pilot to the commercial-sized reactor, having maintained or improved the ratio of  $Q/V$  (see Equation (26)), the linear drift velocity past heat-transfer surfaces should also be maintained or improved. The average linear drift velocity  $v$  will be described as in Figure 4 by

$$v = \frac{Q}{\pi/4(D_1^2 - D_2^2)}. \quad (27)$$

### Solution to a Typical Design Problem

To illustrate a typical application of the design methods previously discussed, assume a pilot-plant batch reaction. The reactor is of the type shown in Figure 4, with 24-in. I.D. by 36-in. straight-side height, working capacity 65 gal., draft tube 4-in. I.D., dual 3-in. diam. by 3-in. pitch-

propeller mixer assembly rotating at 1750 r.p.m. from a  $\frac{1}{4}$ -h.p. motor.

The problem involves the conversion of an available vessel 72-in. I.D. by 96-in. straight-side height, holding capacity 1800 gal., to a continuous reactor. The production rate for the 1800-gal. vessel must be determined and mixing equipment selected. A comparison of the production capacity of the continuous reactor against its use as a batch reactor is also wanted. If used as a batch reactor, the reaction time would be the same as for the batch pilot reactor. However, the batch reactor would operate 85% full, and the charging time would be 18 min., the discharging time 30 min., and, heating-up and cooling-down times 40 min.

To develop the curve of  $fC_{A_0}$  vs.  $K$  as in Figure 2, data for the pilot-plant batch reaction of the strategic component  $A$ , concentration vs. time is accumulated. Such typical data are given in columns 1 and 2 of Table 2. From columns 1 and 2,  $K$  can be determined by graphical differentiation, resulting in column 3. The fractional conversion  $f$ , column 4, can be computed as well from columns 1 and 2 by dividing the difference between  $C_0$  at time zero and  $C_0$  at the other time measurements by the value of  $C_0$  at time zero. The values of  $fC_{A_0}$  in column 5 follow by multiplying the values of  $f$  in column 4 by the value of  $C_0$  at time zero. From columns 3 and 5 the operating line of Figure 2 can be drawn.

Since a one-vessel continuous-reactor system is to be used, the full graphical solution for the economic optimum number of

TABLE 2.—TYPICAL REACTION VELOCITY DATA

(1) Time, min.	(2) $C_0$ , moles/ liter	(3) $K$ , moles/ liter· min.	(4) $f$	(5) $fC_{A_0}$
0	5.0	.....	0	0
2	3.4	0.75	0.32	1.6
3	2.7	0.50	0.46	2.3
5	2.0	0.27	0.60	3.0
10	0.9	0.17	0.82	4.1
13	0.5	0.08	0.90	4.5
16	0.3	0.035	0.94	4.7
21	0.2	0.01	0.96	4.8
50	0.05	0.001	0.99	4.95

vessels can be omitted. (This particular problem was in fact chosen to spare the reader from the straightforward but space-consuming operations involved.)

The continuous-production rate attainable with the available vessel will depend upon the fractional completion of reaction set for the process. From the data in Table 2 the necessary computations can be performed. These computations for each of the fractional completions of reaction of Table 2 are summarized in Table 3. For example, typical entries in Table 3 were computed as follows:

To achieve a fractional conversion of 0.96, the  $K$  for the reactor will be 0.01 mole/liter-min. and  $fC_{eq}$  will be 4.8 moles/liter, from Table 2. The necessary reaction time from Equation (7):

$$\theta = \frac{fC_{eq}}{K} = \frac{4.8}{0.01} = 480 \text{ min.}$$

TABLE 3.—COMPARISON OF PROBLEM RESULTS FOR DIFFERENT FRACTIONAL COMPLETIONS OF REACTION

Fractional completion of reaction	Production rate, gal./min.	Ratio of continuous to batch production rates
Batch operation	Continuous operation	
0.32	17.0	850
0.46	16.8	392
0.60	16.4	162
0.82	15.5	74.5
0.90	15.3	31.9
0.94	14.8	13.4
0.96	14.2	3.75
0.99	12.0	0.363
		0.0302

The volumetric throughput rate will be

$$F = \frac{I'}{\theta} = \frac{1800}{480} = 3.75 \text{ gal./min.}$$

By comparison the batch-reactor-production capacity when operating 85% full and taking into account the charging, discharging, heating-up and cooling-down times will be

$$\frac{(0.85)(1800)}{(20 + 18 + 30 + 40)} = 14.2 \text{ gal./min.}$$

Thus, for this condition, as a continuous reactor the production rate is  $3.75/14.2 = 0.26$  the batch-production capacity.

From Figure 5, the theoretical, circulating capacity  $Q$  in the pilot-plant batch reactor fitted with 3-in. diam. propellers will be 150 gal/min. From Equation (26) the recycle rate of the pilot batch reactor is  $(150)/(65) = 2.3$  passes/min. To conserve this value in the commercial continuous reactor, the minimum  $Q$  should be  $(2.3)(1800) = 4,130 \text{ gal./min.}$  Thus, from Figure 5, the continuous reactor can be fitted with a 15-in. diam.  $\times$  15-in. pitch-propeller type draft-tube exhausting mixer rotating at 400 rev./min. This will consume approximately  $1\frac{1}{2}$  hp. in water (see Fig. 6).

The linear drift velocity past the heat-transfer coils in the pilot batch reactor will be theoretically from Equation (27) =  $(150)/(7.5)(\pi/4)(2^0 - 0.33^0) = 6.7 \text{ ft./min.}$  In the commercial continuous reactor using a draft-tube diameter of 16 in. to accommodate 15-in. diam. propellers the linear drift velocity will be  $= (4,130)/(7.5)(\pi/4)(6^0 - 1.33^0) = 20.5 \text{ ft./min.}$  This is an improvement over the pilot batch reactor for heat-transfer purposes. Here, a draft-tube diameter adjustment could have been made if necessary. If two additional 15-in. diam. propellers were employed

as dispersing mixers inside the draft tube of the commercial continuous reactor, the total mixer horsepower consumption would become  $3 \times 1\frac{1}{2} = 4\frac{1}{2} \text{ hp.}$

### Batch vs. Continuous Operation

The solution to the typical design problem as summarized in Table 3 makes possible a comparison of batch vs. continuous operation to determine the desirability of converting to continuous operation. General conclusions can be drawn which also would hold true had a multivessel system been calculated, although with a multivessel system the calculated results would have shifted in favor of the continuous system.

Table 3 portrays the sensitivity of the production capacity of a continuous reactor with the fractional completion of reaction achieved. In going from 32 to 99% completion of reaction the batch-production rate remained relatively constant, while the continuous-production rate decreased by about a factor of 2000. Of course, the variation in the batch rate would have been more pronounced if the dead times (i.e., charging, discharging, heating up, cooling down) had not constituted so large a percentage of the over-all processing time. However, even with the elimination of dead times a factor of 10 in batch-production rate variation hardly compares with a factor of 2000 for the continuous rate variation. Practical continuous plant operation, especially the instrumentation and control, demands that scrupulous attention be given in the process design to this sensitivity.

Table 3 also exhibits the sometimes unfavorable production-capacity characteristics for continuous-reactor systems notwithstanding the benefits which accrue, as were enumerated at the outset. These production-capacity characteris-

tics may increase the cost of production when compared to batch operation. Usually, these unfavorable rates ensue when a high percentage completion of reaction is to be achieved, generally 95% or greater, coincident with extended reaction times, generally  $\frac{1}{2}$  hr. or more when measured batchwise. This is usually the case with organic chemical systems. With inorganic systems reaction times are usually so short, or instantaneous, that an advantage for the continuous-reactor system will accrue in spite of a high percentage completion of reaction.

As the number of reactors employed in series is increased, the production-rate comparison shifts in favor of the continuous system. The method previously presented for determining the economically optimum system should be used to determine the minimum-cost continuous system. This result can then be compared with the batch system cost. In the final analysis production capacity per unit volume of equipment is only part of the story. Other factors (e.g., labor costs, product uniformity, etc.) exert their influence on the over-all cost of production. These other factors may, and usually do, operate to select the continuous-reactor system even though the production capacity per unit volume of equipment may favor the batch system. Table 3 points up in bold relief the advantage in production capacity per unit volume that a continuous-reactor system can enjoy over a batch system. It will be noted that the advantage lies primarily where the final percentages of reaction completeness can be sacrificed. From Table 3 it is apparent that the ratio of continuous-to-batch-reactor production rates roughly follows the exponential reaction-velocity curves typical of the classical orders of

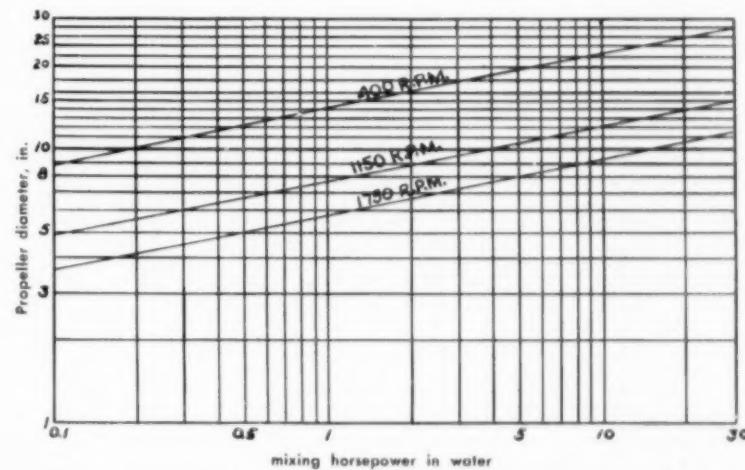


FIG. 6. Propeller Mixer Power Consumption (where diameter = pitch)

reaction. When the fractional completion of reaction is high, the reaction rate is low, and in turn a low production rate from a continuous reactor is to be expected. However, resort to a multiple-reactor system, so that the first reactors in the series operate on a higher reaction rate, can markedly improve the over-all result. In fact, where high degrees of reaction completion are required, a multiple-reactor-series system is clearly indicated and usually prevails from economic considerations. These multiple systems most often do not exceed four to six reactors in series.

### Summary

To obtain the benefits from continuous-mixed-tank-reactor systems pilot-plant batch data can be used to advantage for design purposes. Both a scale-up and a conversion problem are involved. The elements of the problem involve reaction kinetics, economics, short-circuiting, and sometimes heat transfer. The liquid-phase matrix in which these problem elements are resolved exerts its influence through the mixing system employed and the flow patterns obtaining.

Working against continuous reactors is the dilution or reduced-concentration potential for reaction. The reaction time for a continuous reactor can be theoretically written, and a graphical solution to the problem of multiple-reactor systems can be used. From this information the number of reactors required in series, their size, and their production capacity can be ascertained.

The economically optimum continuous system can be established either analytically or graphically. This optimum results because, as the number of reactors employed in series increases, the fixed charges increase, while the manufacturing charges decrease. As the number of reactors in a series is increased, the total volume of the system decreases.

Because of short-circuiting, the effluent from the reactor system may be made up of portions which had stayed for various periods of time in the system. The extent of short-circuiting may be quantitatively evaluated in terms of the number of reactors in series, the in-vessel recirculation rate, and the volumetric throughput rate for the system. The importance of the in-vessel circulation rate for the pilot-plant batch reactor for scale up, and conversion to the commercial continuous reactor is demonstrated if the deleterious effects of short-circuiting are to be taken into account.

For scale-up purposes of temperature-controlled reactions the linear drift velocity, established by the mixing system, past heat-transfer surfaces should be

maintained or improved. Moreover, the effectiveness of the mixing action directly bears upon the over-all coefficient of heat transfer.

The solution to a typical design problem makes possible a comparison of batch vs. continuous operation to evaluate the desirability of going to continuous operation. The production rate for a continuous-reactor system is highly sensitive to the fractional completion of reaction achieved and should be carefully scrutinized in the process design especially as instrumentation and process control is affected. The problem covers a range of operation and helps establish generalizations for the conditions when continuous operation excels from the production-rate viewpoint and the batch system yields a more favorable result.

### Acknowledgments

Grateful acknowledgment is made to Donald R. Mason, Bell Telephone Laboratories, for his valuable suggestions leading to a revision of the reaction kinetics presentation as originally included in this paper. R. B. MacMullin, R. B. MacMullin Associates, has been of invaluable assistance in the strengthening of the presentation, especially as it conforms with nomenclature previously developed by other workers in the field. W. E. Lobo, M. W. Kellogg Co., and R. W. Jones, Monsanto Chemical Co., also have been liberal with their advice and constructive criticism after review of the manuscript.

### Notation

$C$  = reactant concentration

$D_1$  = reactor diameter

$D_2$  = draft-tube diameter

$f$  = fractional conversion of reactant to product

$F$  = volumetric throughput rate

$K$  = reaction rate

$m$  = number of reactors in series

$n$  = number of recycles in reactor

$N_t$  = recycle rate

$p$  = proportion of discharge having made only one pass in reactor

$q$  = proportion of material remaining in reactor after having made only one pass

$Q$  = volumetric recirculation rate in reactor

$t$  = time

$v$  = linear drift velocity

$V$  = reactor volume

$\delta$  = the time required for a single pass from inlet to outlet

$\theta$  = nominal holding time of reactants in reactor

### Subscripts

1, 2, 3, 4 . . .  $n$ , refer to reactors 1, 2, 3, 4 . . .  $n$  in series  
0 refers to feed stream to first reactor in series  
 $A$  refers to reactant  $A$

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### Discussion

**C. R. Bartels** (E. R. Squibb & Son, New Brunswick, N. J.): Can you give us an idea of the relationship which must exist at equal production rates for batch and continuous reactions, and degree of completion and dead time? It seems to me that is the break-even point and there must be a simple way of relating these.

**A. P. Weber:** I don't know of any such simple relationship. It depends upon the specific process. It depends also upon the economics dictating the mechanical design for the process. The process and mechanical design, together, would make for a different relationship for each plant system.

**E. F. von Wettberg, Jr.** (Du Pont Co., Wilmington, Del.): I agree re-

garding the importance of continuous reaction systems. They are certainly vitally necessary today as components of continuous processes. Mr. Weber's proposition of using experimental batch data as the basis of design for continuous reaction systems has received fairly general acceptance. This is indicated by its use by many recent investigators, many of whom he has listed in the bibliography.

The author recognizes certain necessary assumptions such as thorough mixing, constant feed rate, and composition. He also, in the presentation, has mentioned some of the other implicit assumptions. I refer you for further details to Jones (3). There is one of those points which I think need some further emphasis; namely, the rate of reaction, or what the author calls the strategic component, must depend only on its concentration. I think it needs to be said there are a good many cases encountered, in practice, where this assumption is not valid. Consequently, we need to check back to find out whether it works the same way in a continuous process as in batch process, by making small-scale continuous tests, as well as batch tests.

I also think it should be emphasized that when good batch reaction-rate data are available and they are entirely applicable, then it is only necessary to determine the slope of the line relating concentration to time at the particular concentration of interest in order to indicate the reaction rate. Of course, similarly, if the reaction rate can be easily expressed as an exact differential equation, you can do the same thing analytically. Following along the same lines, the size of multiple reactors can be similarly determined by Jones' method (3) or another method proposed (1).

**R. B. MacMullin** (R. B. MacMullin Associates, Niagara Falls, N. Y.): One of the references cited by A. P. Weber is a paper by R. B. MacMullin and Matthew Weber (4). The present Mr. Weber is no kin of the prior Mr. Weber.

The graphical procedure described for determining the composition of the effluent from the reactors of a continuous-flow stirred tank reaction system is essentially the same as that described by R. W. Jones (3). In Figure 2 of Mr. Weber's paper, the co-ordinates are interchanged, compared to the Figure 4 of Mr. Jones' paper.

Mr. Weber's derivation of retention time is based on consideration of the pumping rate of the agitator as related to feed rate, and the number of passes a particular particle takes while retained in the reactors. Previous derivations were based on consideration of probability in a substantially homogeneous

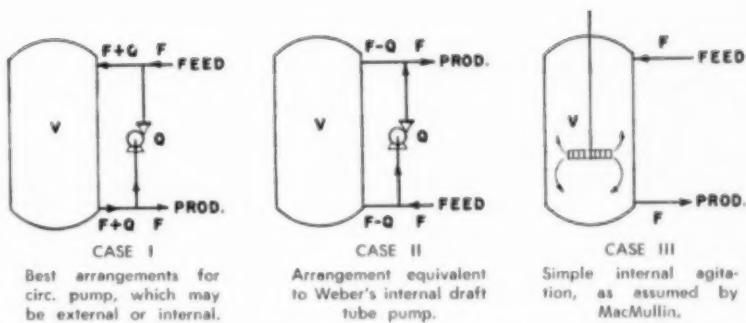


FIG. A. Three Possible Circulating Arrangements in a Single Stage of Continuous Mixing.

medium. Mr. Weber's method is essentially that of difference calculus; the probability method made use of differential calculus, at least as regards the state of affairs in any particular reactor. I find that the two methods are concordant only if the recycle rate  $Q/F$  is large, say 20 or larger.

Using Mr. Weber's symbols:

$$\text{time to make one pass} = \frac{V}{Q}$$

$$\text{time to make } n \text{ passes } t = n \cdot \frac{V}{Q}$$

$$\text{nominal holding time } \theta = \frac{V}{F}$$

$$\therefore \text{retention} \quad t = n \cdot \frac{F}{Q} \cdot \theta$$

We must now consider three possible arrangements for introducing feed (see Figure A):

Since  $p$  = fraction of outflow having made only one pass,

$$\text{For Case I, } p = \frac{F}{F+Q}$$

	$t/\theta$	$p$	$n$
Case I .....	1	.5	1.0
Case II .....	1	.5	2.0
Case III .....	1		

$$\text{whence } \frac{F}{Q} = \frac{p}{1-p}$$

$$\text{and } t = n \cdot \frac{p}{1-p} \cdot \theta$$

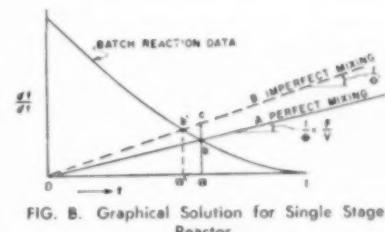


FIG. B. Graphical Solution for Single Stage Reactor.

Instead of the calculated degree of reaction (point a), a lesser value is obtained (point a').

$$\text{Retention efficiency } E_r = \frac{\theta'}{\theta} = \frac{(ab)}{(ac)}$$

$$\text{or } p = \frac{t}{t+n\theta}$$

For Case II (used by Weber in his derivation)

$$p = \frac{F}{Q}$$

$$\text{whence } t = n \cdot p \cdot \theta$$

If we define  $y$  as the fraction of the feed retained for time  $t$ , then

$$y = (1 - p)^n$$

For Case I:

$$y = \left(1 - \frac{t}{t+n\theta}\right)^n$$

For Case II:

$$y = \left(1 - \frac{t}{n\theta}\right)^n$$

For Case III, as in MacMullin's derivation,

$$y = e^{-t/\theta}$$

It can easily be shown that for all values of  $n$ ,

$$y_I > y_{II} > y_{III}$$

Example:

	$y$	$p$	$n$	$y$
Case I .....	.500	.1	9	.387
Case II .....	.250	.1	10	.348
Case III .....	.368			.368

The higher the recycle rate  $1/p$  (that is, the smaller the value of  $p$ ), the more closely does the retention time calculated by Case I and Case II approach the true value calculated by Case III.

Since the over-all rate of reaction depends on the holding time of the elements of flow in the reactor, it is obvious that Case I will give too high a calculated conversion, and Case II, too low a calculated conversion, as compared to Case III.

So far, both Mr. Weber and all previous contributors to the theory of continuous stirred reactors have considered only the kind of short-circuiting one obtains with well-agitated reactors, in which the tank contents are substantially homogeneous. If now there is some sort of short-cut, or channelized flow between

inlet and outlet, so that the tank contents are *not* homogeneous, it is obvious that some portion of the flow will have a shorter nominal holding time  $\theta$  than the rest of the flow. This will cut down the average value of  $\theta$  and will lower the conversion in a reacting system. The purpose of the agitator is to prevent the channeling and to approximate a homogeneous condition. It therefore occurs to me that it should be possible to evaluate the efficiency of a stirrer by studying the conversion rate of a reacting system whose kinetics are known.

Referring to Figure B in my comments here, the curved line represents the known conversion rate  $df/dt$  as a function of  $f$ . The line A is drawn through the origin (if the feed is unreacted) with a slope equal to  $1/\theta = F/V$ , as in the Jones graphical method. The point of intersection  $f$  gives the calculated conversion  $f = a$ , assuming homogeneous mixing.

If, now, it is observed that the actual conversion is somewhat less, say  $f = a'$ , this means that the agitator is not doing its stuff. Locate the point  $b'$  on the rate of reaction curve, and connect it with the origin. The line B now represents the actual operating line, with a slope  $1/\theta'$ .

We can now define the retention efficiency as follows:

$$E_r = \frac{\theta'}{\theta} = \frac{ab}{ac}$$

We are now in a position to try out the effectiveness of different stirrers in a given tank, and also the effect of revolutions per minute and horsepower on the effectiveness of a given stirrer. There are no limitations as to type of agitator—it can be one of Mr. Weber's draft tubes, or a propellor, or a turbine, or a gate agitator, or merely a stream of compressed air.

One doesn't have to look far to find a suitable reacting system. First-order systems, particularly organic, will probably be the most suitable. Holding times should be adjusted to obtain a conversion in the middle range—say 30 to 70%.

I feel that this method of approach to the study of mixing has some merit and that it should be investigated. One of the merits of Mr. Weber's paper is that it has stimulated some of us to thinking beyond the immediate scope of its contents.

**R. W. Jones** (Monsanto Chemical Co., Springfield, Mass.): Albert B. Newman (now deceased), formerly professor at the City College of New York, has written the editor of *Chemical Engineering Progress* (5) pointing out that the graphical method presented in my earlier paper (3) and discussed here by

Mr. Weber is a generalization of the graphical method presented by Eldridge and Piret (2), who limited themselves, quite unnecessarily, to reactions of known order.

Mr. von Wetberg made some pertinent comments. There is a very fundamental difference between the assumptions and conditions necessary for Mr. Weber's, Eldridge and Piret's, and my essentially identical graphical methods and assumptions and conditions necessary for the analytical method presented here by Mr. Weber, and the general graphical method first presented by Mr. MacMullin in 1935 (4). Mr. Kandiner (now with the Barrett Division in Philadelphia) first pointed out to me that Mr. MacMullin's graphical method gave different results from mine on identical theoretical data for reaction orders other than first.

The difference is essentially this: Mr. MacMullin's graphical and Mr. Weber's analytical methods both make the assumption that the degree of completion of the reaction for each discrete molecule or particle depends only on the time that the molecule or particle remains in the continuous reaction system and is independent of the environment or path followed by the particle. Mr. Weber's, Eldridge and Piret's and my graphical method, however, assumes that the reaction rate is a function solely of the concentrations of the reactants and not of their past history in the reaction system.

For example, let us take a three-reactor system and watch incremental particles travel through the system. One such particle or molecule may remain in the first reactor for 99% of its total time and then pass through the last two in 1% of its time in the system. A second particle or molecule might stay in the first and second reactors only 1% of its time, and then remain in the third reactor for 99% of its time in the system. Mr. MacMullin's graphical method and the analytical method of this paper assume that, provided the total times spent in the above system were the same, both particles or molecules would have undergone the same amount of reaction regardless of the concentrations of reactants in the first and third reactor. In general, such an assumption will not be true.

I believe that the assumptions necessary for the graphical method presented by Weber, Eldridge and Piret, and myself will be valid for a far greater number of cases than the assumption required above. Both methods can be wrong, but you should determine by experiment—and I believe it can normally be done by a batch-type experiment—which, if either, of the two assumptions is valid.

I would also like to suggest a method whereby the general graphical method and its assumptions can be applied to the draft-tube type of reactor for which Mr. Weber has proposed his analytical approach. You could use the same method as is illustrated by Figure 2 except you would need to travel up the  $fC_0$  vs.  $K$  "operating line," a distance which would correspond to the amount of reaction occurring during the turnover time ( $1/Q$ ) in the draft-tube reactor before constructing the next "operating diagonal."

**A. P. Weber**: Very briefly, with the proportions I give, I am taking a statistical approach. This probability approach allows for deviations of different magnitude at any instant. However, it mathematically describes the probable conditions at any instant.

**P. M. Reilly** (Polymer Corp., Sarnia, Ont., Canada): Mr. Weber talked about reaction time, economics, and heat transfer as being the principal factors affecting scale-up. There is one other matter which perhaps should be emphasized—he touched on it a little bit. That is the effect of the number of vessels on contact time distribution. Where there are a number of vessels in series in such a case as has been discussed, the contact time distribution varies widely. For instance, with a continuous reactor consisting of a single stirred tank with no draft tube, there is a wide distribution of contact times with the most probable ones very short. If the total volume of the system and the flow rates are held constant and the number of tanks in series increased, the most probable contact time increases and the distribution becomes narrower.

Now in certain types of reactions that is an important consideration, in particular the manufacture of synthetic rubber by emulsion polymerization. In that case the molecular weight distribution has great effect on product quality and molecular weight distribution.

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(Presented at A.I.Ch.E. White Sulphur Springs (W. Va.) Meeting.)

# Process Engineering

## Economics of Acetylene by Wulff Process

**A**cetylene, if available at an attractive price, is an important raw material for the synthesis of a wide variety of useful chemicals. Until recently, all acetylene used in the United States was prepared by the classic method of mixing calcium carbide with water, and large-scale chemical applications of acetylene have been keyed to the economy of calcium carbide. Wherever possible, process units which required acetylene were located close to the areas where calcium carbide is manufactured. When acetylene was compared with other raw materials that might be used for synthesis, the comparison and selection were made on the basis of carbide-acetylene.

Recent developments now make it practical to produce large commercial quantities of acetylene by the thermal decomposition of natural gas or light hydrocarbons or both. The Wulff process described in this article is an example of such an operation.

Production from light hydrocarbons changes the economic picture of acetylene in those areas where low-cost natural gas, ethane, or propane is available. Accordingly, it is in order to consider, for those processes in which acetylene is the required raw material, the relative profitability of acetylene from carbide, and acetylene from the thermal decomposition of light hydrocarbons. Also, it is proper to re-evaluate the relative profitability of syntheses based on acetylene with those based on other competing raw materials.

A complete analysis of the relative economics of acetylene *vs.* a competing

raw material requires cost information on:

- (a) Production of acetylene by the alternative routes.
- (b) Production of the competing raw material.
- (c) The alternative synthesis operations.
- (d) The effect of synthesis plant location on cost of raw materials and on freight costs for shipping the final product to market.

This paper will give the basic information needed to determine the cost of producing acetylene from light hydrocarbons by the Wulff process. Additionally, as an example of the application of these data, there is presented, for two locations, an economic comparison between carbide and Wulff process acetylene. The comparison between acetylene and competing raw materials (as ethylene) is outside the scope of this paper.

### Acetylene from Light Hydrocarbons

The production of acetylene by the decomposition of light hydrocarbons may be accomplished, broadly, either through the application of heat from combustion or by passing the feed through an electric arc. A number of processes employing one or another of these means have been studied, each with certain elements in common. First, a "cracking device" (furnace or electrical reaction chamber) together with a collection of coolers or scrubbers, producing a dilute stream of acetylene; second, a group of compressors to boost the dilute stream to a pressure suitable for recovery and separation of the acetylene, and third, a recovery and purification section gen-

erally consisting of absorption and distillation equipment.

At present, the processes which have reached the stage of commercial practicality employ thermal decomposition of the feed. For these pyrolyses, the conditions for obtaining substantial yields of acetylene from light hydrocarbons are: temperatures above 2200° F. (the exact temperature varies with feed composition), short contact time, and low partial pressure of acetylene at the reaction zone.

The Wulff process was invented in 1925. It was the first recognition of the simple statement that substantial yields of acetylene can be obtained by subjecting vaporizable hydrocarbons to high temperatures at low partial pressures for short periods of time. The delay in developing the process to a commercial scale was caused by the need for demonstrating a practical technique of achieving high temperatures and short contact times in equipment that would operate reliably without unreasonable maintenance.

As the process is constituted today, its distinguishing feature is the use of a regenerative furnace to achieve pyrolysis of the feed. The low partial pressures are accomplished by a combination of the use of vacuum (the furnace operates at about 15 in. of Hg abs.) and steam dilution of the feed. The balance of a complete Wulff plant consists of the necessary coolers, scrubbers, blowers, compressors, absorbers, and fractionating equipment needed to separate and purify the acetylene.

A small commercial demonstration plant has been in operation for nearly two years. It has been in almost continuous commercial production of acetylene for over a year, and the furnace has operated without maintenance or repairs.

### Process

To help define the data to be presented, Figure 1 shows a flow diagram of a Wulff process acetylene plant. The following is a brief process description:

Multiple furnaces in parallel are used to provide continuous flow of "cracked gas." Each furnace alternates between a "heating" and a



T. Weaver

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"cracking" step. At any given time a mixture of feed vapor and dilution steam flows to one half of the total number of furnaces, while air and fuel gas for heating flow to the other furnaces. Each furnace is reversed approximately every sixty seconds.

Flue gas effluent from the heating step flows from the furnaces to a blower and is exhausted to the atmosphere. Cracked gas effluent from the furnaces is cooled by direct contact with water to condense and scrub out tars (no carbon black is produced); it is then compressed to atmospheric pressure by the cracked gas blower, flows through a Cottrell precipitator for final cleanup, and is compressed to recovery-system pressure in the main compressors.

The compressed gas flows to the diacetylene absorber where it is contacted with a small stream of lean solvent to remove the bulk of the diacetylene contaminant and some of the other higher homologs of acetylene. Solvent from the bottom of the diacetylene absorber flows to the diacetylene stripper where these contaminants are stripped out with a small stream of residue gas, which then in turn goes to the furnaces as fuel. The stripped solvent returns to the lean solvent surge tank.

The main gas stream flows from the diacetylene absorber to the acetylene absorber where it is contacted with a major portion of the lean solvent. Residue gas from this absorber is divided. Small portions of it are used for stripping in the diacetylene stripper and final stripper, and then go to the furnaces for fuel. The major portion is scrubbed with water to recover vaporized solvent, and then flows to the main fuel-gas system where it is used as fuel for the furnaces, gas engines, or boilers.

Rich solvent from the acetylene absorber flows to the rich solvent stabilizer. In this column, which is reboiled and refluxed with a small stream of lean solvent, ethylene, carbon dioxide, methane, hydrogen and other constituents more volatile than acetylene are taken overhead. These are then recycled through the main compressors to the acetylene absorber where they are eventually rejected.

Rich solvent flows from the bottom of the rich solvent stabilizer to the acetylene stripper. In this column, which is reboiled and refluxed

with a small stream of lean solvent, the acetylene product is taken overhead to storage, while methylacetylene and other less volatile constituents, including the balance of higher homologs of acetylene, are retained in the bottoms. This solvent stream then flows to the final stripper where these higher homologs of acetylene are removed by stripping with residue gas.

In the course of heating solutions of acetylene and its homologs, a small fraction polymerizes to a tarry material. To remove this polymer from the solvent, a small slip-stream of the lean solvent is withdrawn from the solvent surge tank, diluted with water, and then sent to the polymer decanter where the polymer, now present as a separate phase, settles out, and is withdrawn. The aqueous solution then joins the bottoms from the fuel gas scrubber and flows to the solvent rectifier, where water is removed by distillation. The purified solvent is then returned to the system.

In certain applications where feed has an unusually high value, the raw-feed requirements and the net production of residue gas to fuel may be minimized by recycling a portion of the residue gas along with the fresh feed to the furnace. This achieves a higher yield of acetylene for each unit of feed, at the expense of larger equipment for the plant. For such a "recycle" operation, the recycle stream is made up of the gas from the diacetylene stripper and the final stripper.

#### Data Basis

Yields and compositions used here are based on data obtained in the small commercial demonstration plant. However, a word of comment. While the demonstration plant has been operated continuously to provide data for plant design on propane and on natural gas, only a few runs have been made on ethane. These do not constitute a firm basis for final plant design, but, owing to the interest in ethane as charge stock, a conservative interpretation has been included to provide an approximate picture.

In the studies presented here, the acetylene plant is treated as one process unit in a large chemical plant. Thus, capital costs are given for a "battery limits" plant, with steam and cooling water supplied from a central plant. In computing operating expenses, the values assigned to steam and circulated cooling water are intended to be consistent with the cost of fuel for the area considered, and high enough to include fixed charges and operating costs for the central utility facilities. By similar reasoning, labor charges for administrative personnel and such service groups as accountants, chemists, and watchmen are on a part-time basis.

For the natural gas feed stock, a typical natural gas having a gross heating value of 1100 B.t.u./std.cu.ft. has been assumed. The ethane feed stock has been taken as containing 90% ethane. In the case of propane, a typical commercial grade material having a purity of approximately 90% has been assumed.

Each of the operations considered is on a "once-through" basis; there is no recycle of residue gas with the furnace feed.

It has been assumed that the boiler plant and other furnace fuel requirements for the entire chemical plant will be large enough to consume all the residue gas from the acetylene plant. In most instances there will be no question on this point. Accordingly, residue gas is credited to the process on a B.t.u. basis, equivalent to fuel.

Capital and operating costs, and utility requirements are based on using gas-engine drives for the main compressors. Where conditions favor steam-driven centrifugal compressors, this substitution may be made with attendant savings in capital and utility costs.

In connection with operating expenses and fixed charges against capital investment, sufficient background information is shown in a sample tabulation to permit adjustment of the final figures for the variations in unit costs and percentages normally encountered among different organizations.

As expected, the purity of the acetylene affects the capital and operating costs of the recovery and purification equipment. In the cases presented, the expected product is 99 vol. % acetylene. The principal impurities are 0.3 vol. % methylacetylene, 0.5 vol. % carbon dioxide, and 0.2 vol. % ethylene.

Capital costs shown cover the complete "battery limits" including:

All buildings in process area, such as operating control room, compressor house and electrical switch house.

Acetylene product gas holder to store full product for one hour.

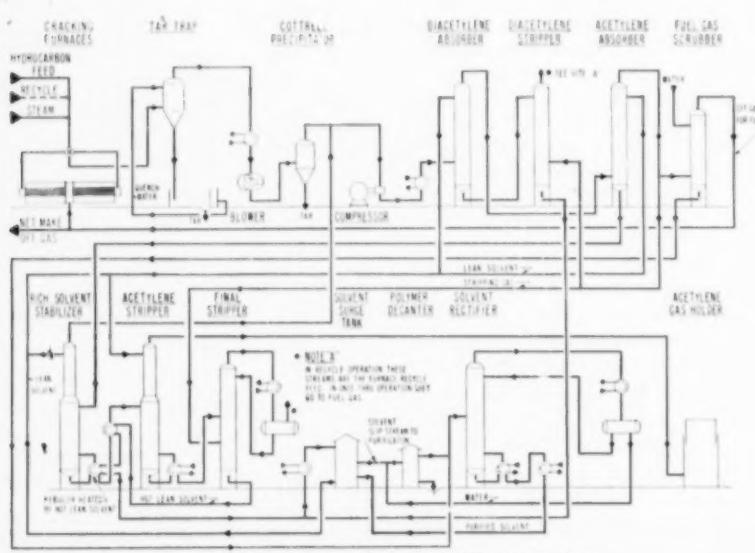


Fig. 1. Flow diagram of typical Wulff process plant.

#### Propane storage tanks:

For the case of propane feed, capacity is provided for five and one-half days' normal feed requirements.

For natural gas or ethane feed, capacity is provided for approximately three days' emergency operation on propane.

#### Initial charge of solvent:

Operating spare pumps and drives. Spare parts and materials for warehouse stock are not included.

#### Cost of engineering and design:

#### Contractors' fees:

### Costs of Wulff Process Acetylene

Table 1 shows material balances and utility requirements for three Wulff acetylene plants, located in the Gulf Coast area, each to produce 20,000,000 lb. of acetylene a year.

Table 2 shows, for each of the three plants, capital costs, fixed charges, operating expenses, royalty and total "factory cost" of the product acetylene. Royalty included in the table is computed on the "running basis," equal to the sum of \$10,000 a year, plus one-eighth cent a pound of acetylene recovered. The prices shown for natural gas and propane are current estimates of the long-term market values of these products. The price shown for ethane is estimated to include its value on a heat basis, plus the cost of separating it from a typical natural-gasoline plant residue gas stream.

An annual average stream-day efficiency of 90% has been used in computing the material balances and costs. However, no specific allowance has been made for "load factor," the ratio of actual average operating rate to the nominal or design calendar-day capacity. Load factor is controlled by ability to sell or inventory the final product, and by the amount of extra capacity built into the plant to allow for future market growth. Accordingly, it will vary with the nature of the end product to be made from the acetylene. To correct the figures presented for load factor, the fixed charges against capital, labor costs, costs of supplies and of solvent (all expressed in cents per pound of acetylene product) must be increased by dividing them by the ratio just described to define load factor.

Figure 2 shows for natural gas, ethane and propane feed, the effect of plant size (as measured by acetylene production rate) on capital investment.

Figure 3 shows for natural gas feed, the effect of plant size on fixed charges against capital, operating expenses and "factory cost" of acetylene, for plants located in the Gulf Coast area.

Figure 4 shows the effect that changing the feed to ethane or propane would have on the factory cost of acetylene as a function of plant size, in the same locality.

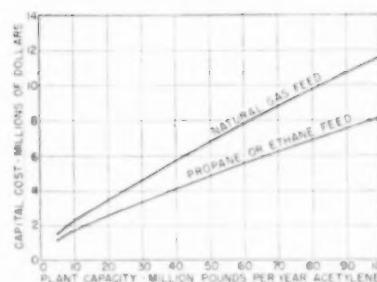


Fig. 2. Capital cost vs. plant capacity for Wulff process acetylene plants.

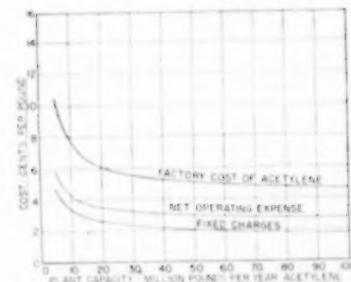


Fig. 3. Effect of plant capacity on factory cost of acetylene for natural gas feed. (Gulf Coast.)

costs of steam and the value of the residue gas as fuel are also higher. To indicate the magnitude of these effects, and to provide background for a comparison to be made at a later point in

TABLE 1.—MATERIAL BALANCES AND UTILITY REQUIREMENTS FOR 20 MILLION lb./yr. WULFF PROCESS ACETYLENE PLANTS

FEED MATERIAL:	NATURAL GAS	ETHANE	PROPANE
<b>MATERIAL BALANCES.</b>			
Feed, M std.cu.ft./day	7,850	1,860	46,800
gal./day			
<b>Yields</b>			
% Feed converted to acetylene *	21.8	53.0	38.4
lb. acetylene recovered/100 lb. feed	16.2	41.4	30.7
<b>Off Gas</b>			
Net excess std.cu.ft./hr.**	458,400	163,800	190,000
Heating value (HHV) B.t.u./cu.ft.	605	457	523
Excess M B.t.u./hr.	276,000	74,800	99,400
<b>Utility Requirements</b>			
Steam (300 lb./sq.in. gage) lb./hr.	83,176	78,976	68,976
Cooling water gal./min.	10,364	7,974	7,350
Electricity, kw.	950	853	889

\* Conversion is % of carbon in feed which appears as carbon in furnace effluent acetylene.

\*\* Excess taken after deduction of fuel for reaction furnaces and gas engine drives for main compressors.

All quantities are on a "stream day" basis. To obtain calendar day rates multiply by 0.9.

TABLE 2.—COST OF ACETYLENE PRODUCED VIA WULFF PROCESS IN GULF COAST AREA

IN PLANTS PRODUCING 20 MILLION lb./yr. ACETYLENE

FEED MATERIAL:	NATURAL GAS	ETHANE	PROPANE
CAPITAL INVESTMENT	\$3,456,000	\$2,561,000	\$2,572,000
cents/lb. Acetylene			
FIXED CHARGES ON INVESTMENT *	2.68	1.98	1.99
Operating expenses			
Steam (300 lb./sq.in. gage) @ 30 cents/M lb.	.99	.93	.82
Cooling water @ 1.5 cents/M gal.	.37	.28	.26
Electricity @ 1 cent/kw.hr.	.37	.34	.35
Natural gas @ 15 cents/MM B.t.u.	2.13	—	—
Ethane @ 1 cent/lb.	—	2.42	—
Propane @ 4 cents/gal.	—	—	3.06
Solvent @ 40 cents/lb.	.39	.39	.39
Labor **	.61	.61	.61
Supplies	.10	.10	.10
Fuel gas credit @ 15 cents/MM B.t.u.	—1.65	—.49	—.53
Royalty	.18	.18	.18
Total factory cost	6.17	6.74	7.13

\* Fixed charges at 15.5% a year to include depreciation, taxes, insurance, interest and maintenance.

\*\* Labor costs include direct operating labor costs plus part-time services of chemist, accountant, watchman, superintendent and administrative personnel, plus 22% for vacations, insurance and benefits.

this paper, data are presented for the area of the lower Ohio River Valley. Table 3 shows for each of the three feed stocks, the factory cost of Wulff process acetylene in the lower Ohio River Valley. As before, prices taken for natural gas and propane are based on current estimates of their long-term market values; the price for ethane includes its value on a heat basis for this locality, plus the cost of separating it. (For this case separation is assumed to be performed in a stripping plant located on one of the major natural-gas transmission pipelines.)

Figure 5 shows for natural gas, ethane and propane, respectively, the effect of plant size on cost of acetylene in the lower Ohio River Valley.

### Wulff vs. Carbide

It is of interest to compare Wulff process acetylene and acetylene prepared from calcium carbide.

The generation of acetylene from carbide is accomplished by reacting the carbide with water. The generator effluent is scrubbed to remove hydrogen sulfide and phosphine, and is then delivered at a purity of about 99½%. The equipment required for generation and scrubbing is of quite standard design and involves a nominal capital investment. The major cost is that of the carbide itself, with transportation of the carbide a potentially significant factor.

Calcium carbide is manufactured on a large scale only in those localities which combine low cost electric power with supplies of high quality limestone and coke. Thus, when carbide acetylene is to be used at a point removed from these localities, it is necessary to ship the carbide, rather than manufacture it at the point of use. For substantial operations, calcium carbide is shipped to the user in steel hoppers of 5-ton capacity, designed to be handled on a flat car and to couple directly to the acetylene generator. In such a case the freight charges for moving the full and empty hoppers, and the "fixed charges" against the capital investments in hoppers may become a large factor in the total cost of the carbide acetylene.

In recent years there has been a trend toward "on-the-spot" acetylene generation, eliminating costs of freight and rehandling of the carbide. In these cases, large chemical synthesis operations are located adjacent to a carbide manufacturing plant where the carbide manufacturer sets up and operates the generators and sells purified acetylene "across the fence."

Whether the carbide-acetylene user chooses to locate close to an "on-the-spot" generating plant, or to purchase the carbide, ship it to his own location

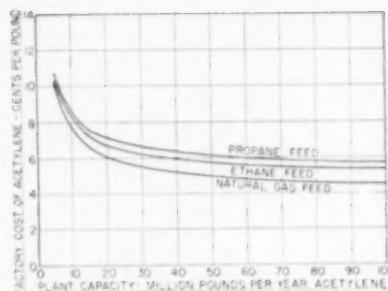


Fig. 4. Comparison of factory costs of acetylene via Wulff process from three feed stocks. (Gulf Coast location.)

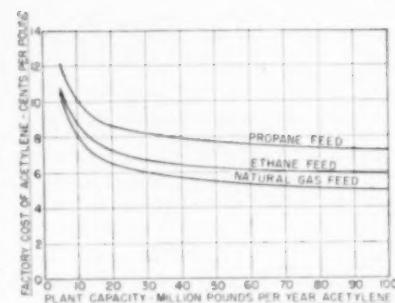


Fig. 5. Comparison of factory costs of acetylene via Wulff process from three feed stocks. (Ohio Valley location.)

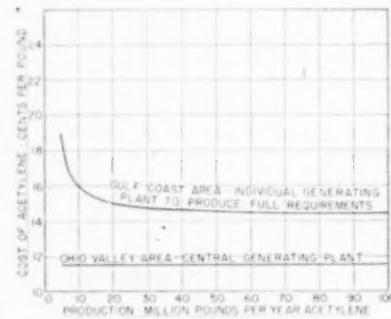


Fig. 6. Cost of carbide acetylene at two different locations.

River Valley, are chosen for comparison with the Wulff process.

In Figure 6, the upper curve shows the total cost of carbide acetylene as a function of annual rate of consumption for individual generating facilities located in the Gulf Coast area. The cost indicated by this curve includes a suitable return on investment in generating facilities.

TABLE 3.—COST OF ACETYLENE PRODUCED VIA WULFF PROCESS IN OHIO VALLEY AREA IN PLANTS PRODUCING 20 MILLION lb./yr. ACETYLENE

FEED MATERIAL:	NATURAL GAS	ETHANE	PROPANE
CAPITAL INVESTMENT	\$3,456,000	\$2,561,000	\$2,572,000
	cents/lb. Acetylene		
FIXED CHARGES ON INVESTMENT *	2.68	1.98	1.99
Operating expenses			
Steam (300 lb./sq.in. gage) @ 37 cents/M lb....	1.21	1.15	1.01
Cooling water @ 1.5 cents/M gal.....	.37	.28	.26
Electricity @ 1 cent/kw. hr.....	.37	.34	.35
Natural gas @ 20 cents/MM B.t.u.....	2.84	—	—
Ethane @ 1.2 cents/lb.....	—	2.90	—
Propane @ 6 cents/gal.....	—	—	4.59
Solvent @ 40 cents/lb.....	.39	.39	.39
Labor ** .....	.61	.61	.61
Supplies .....	.10	.10	.10
Fuel gas credit @ 20 cents/MM B.t.u.....	—2.20	—.65	—.84
	.18	.18	.18
Royalty .....	—	—	—
	6.55	7.28	8.64

\* Fixed charges of 15.5% a year to include depreciation, taxes, insurance, interest and maintenance.

\*\* Labor costs include direct operating labor costs plus part-time services of chemist, accountant, watchman, superintendent and administrative personnel, plus 22% for vacations, insurance and benefits.

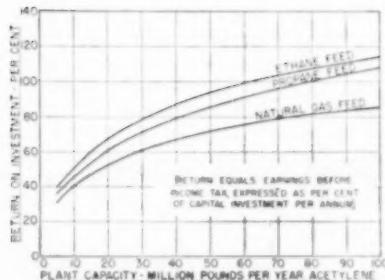


Fig. 7. Return on investment for Wulff process acetylene plants based on cost of carbide acetylene. (Gulf Coast area.)

In Figure 6, the lower curve, a horizontal straight line, shows the price at which it is reported carbide acetylene may be purchased "across-the-fence" from an "on-the-spot" generating plant in the lower Ohio River Valley, on the basis of a long term contract, and high load factor.

Figure 7 shows, for the Gulf Coast area, the difference between the cost of carbide acetylene and the "factory cost" of Wulff process acetylene, for three feeds, expressed as per cent return, before income tax, on capital invested in the Wulff process plant. The significance of the low end of these curves is straightforward. However, since operations using carbide acetylene on the scale indicated by the upper portion of the curves have probably not been seriously considered for the Gulf Coast area, the curves here merely serve to emphasize the point that for this geographic locality the economics of acetylene have been materially changed.

Figure 8 shows, for the lower Ohio River Valley, the difference between the price of carbide acetylene and the "factory cost" of Wulff process acetylene, for three feeds, expressed as per cent return, before income tax, on capital invested in the Wulff process plant. These curves show that for small operations in this area, the economic choice, other things being equal, is to locate the chemical plant adjacent to "on-the-spot" carbide acetylene generating facilities. However, for larger operations, the Wulff process offers an attractive investment.

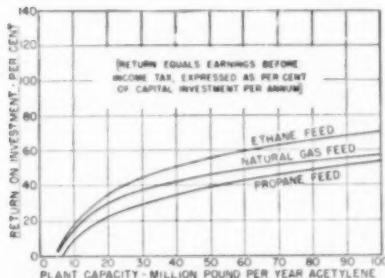


Fig. 8. Return on investment for Wulff process acetylene plants based on cost of carbide acetylene. (Ohio Valley area.)

### Acknowledgment

The author wishes to acknowledge the valuable assistance given by members of the engineering department of The Fluor Corp., Ltd., and to thank The Wulff Process Co. and The Fluor Corp., Ltd., for permission to publish.

### Discussion

E. M. CARTER (Du Pont Co., Inc., Madison, Tenn.): The results you quoted on ethane are interesting, particularly from the return point of view which presumably means increased capacity. The off-gas from the concentration system, whether it be made from natural gas or propane, should have a substantial amount of ethane. Would not plant capacity improve and hence the return on methane, by reusing your off-gas in toto from the acetylene stripper? Also, I was surprised at the curve illustrating capital and investment against capacity—it is essentially straight from a fairly small scale of about a million dollars to about ten million annual capacity. I should think a purification and concentration unit on a large scale would introduce economies.

THEODORE WEAVER: I'll answer the second question first.

I believe the appearance of the curve is somewhat deceptive. Although it may appear to be a straight line, plant cost is found to vary of about the 0.7 power of plant capacity. The reason that this curve is more nearly a straight line than is found in some other process units is the fact that the plant cost includes substantial items for compressors and furnaces, which items vary almost linearly with capacity of the plant.

On the matter of utilization of ethane in the off-gas the amount of ethane is in the order of 2 or 3%. There would be a substantial cost involved in separating ethane to recycle back to the furnace.

F. B. SELLERS (Texaco Co., New York, N. Y.): This process is operated at 15 in. of Hg abs. I presume this to be the optimum operating pressure. What effect on the cost of producing acetylene does atmospheric or even superatmospheric pressure operation have?

THEODORE WEAVER: Acetylene yield at any given temperature and time falls off rapidly as the pressure rises. It becomes difficult to get substantial yields at 1 atm. pressure at these temperatures. One can get it by going to higher temperatures, perhaps, which complicates the refractory problem. The partial pressure of hydrocarbons in the unit is even less than  $\frac{1}{2}$  atm. because of steam dilution. The low pressure is quite significant. The particular pressure we have chosen is perhaps not optimum in terms of the highest acetylene yield, but rather gives the lowest cost of acetylene for a given feed stock.

W. E. LOBO (The M. W. Kellogg Co., New York, N. Y.): Have you an economic comparison with partial oxidation of natural gas with oxygen?

THEODORE WEAVER: We have looked at that seriously. It is not easy to answer completely in a few words, but it comes down to this: each comparison we have made shows that partial oxidation techniques offer a higher concentration of acetylene in the cracked gas stream. This means a less expensive compressor plant. On the other hand, partial oxidation requires an oxygen plant and in each case, the oxygen plant more

than offsets the additional recovery cost.

C. J. MCFARLIN (Air Reduction Co., Inc., New York, N. Y.): In the last figure the return is not only before taxes but also before the battery limits. I doubt that utilities would be available unless specifically provided. Also, if I understand the estimates properly, it is before general and administrative expense, before sales expense, and items of overhead that are inevitable. Also, it is before any allowance for the load factor as influenced by sales. My whole point is that I think this a case of comparing eggs to potatoes. This accurate price of bulk chemical acetylene, does include all these factors. So, some return on investment will be shown when included. The question is: have you worked costs through specific cases?

THEODORE WEAVER: In terms of sales expense we thought we were comparing in the Wulff plant a captive operation where there is not the problem of selling acetylene to the plant user vs. a plant that purchases acetylene at the price shown from a carbide-generating facility.

In terms of the capital charges for the utilities, it was intended that the prices charged for utilities cover the capital charges against them. The values used are in agreement with the values used by some companies operating in that area who contend that they cover the capital charges. Adjustments can be made, and in large-scale operations the capital investment and utility picture displace the curves slightly. The biggest item of cost—more than one-third of it—in the case of the natural gas plant is the fixed charge against the capital investment in the Wulff unit.

C. J. MCFARLIN: Am I to understand that the return on the utility outside the battery limits is in the general order of magnitude of a chemical enterprise, or the same as on the public utility type of return? Or, is it merely that the charges have nothing to do with profit? I am thinking of land, office buildings, and such items as well as power and steam.

THEODORE WEAVER: The values used for utility costs were taken from the practice of one major operating company in that area, who purports that they do contain reasonable allowances for the items you have questioned. Some allowance has been included in the plant investment values to cover the cost of buildings. Although nothing has been provided for land, its normal value is so small in comparison with plant cost in the present case, that it should not have a significant effect on the outcome.

L. J. WINCHESTER (Engineers' Res. & Dev. Lab., U. S. Army Corps, Ft. Belvoir, Va.): Have you considered the marketability and cost of different purities of acetylene products such as a 97% or a 99% pure product, or, on the other hand, a purer product?

THEODORE WEAVER: Lowering the purity below 99% and making small changes in purity say to 97%, does not have a significant effect on price. We have not investigated the case for 99%. Actually, one needs to talk about the impurity concerned. For instance, the carbon dioxide could be removed from this in an amine scrubbing unit, but the methyl acetylene would be more of a nuisance, and we have not been faced with the specific problem of limiting the methyl acetylene below the value mentioned. This value is acceptable to one major chemical company using acetylene in a chemical synthesis. This value is acceptable to at least one major chemical company using acetylene in a chemical synthesis. Some further reduction in this amount of methyl acetylene may be made.

# MARKET SURVEY OF AN INDUSTRY

## Paint, Varnish and Lacquer

Charles Waggaman Berl

THE paint, varnish, and lacquer industry is one of the most important markets for chemicals today. An analysis of production data for the principal products, establishing the trends that have taken place over a period of years and determining the volume of materials required for manufacture of protective coatings is therefore of particular interest to the chemical industry. Also for the purposes of this symposium it illustrates methods which may be employed to make a market survey of an industry.

Background statistics on the size of this industry may be briefly indicated. The United States Census publishes every month the total dollar sales of 680 manufacturers in the paint, varnish, and lacquer industry. This statistical series goes back to 1936 and is estimated to represent about 90% of the total sales of the industry. In 1936, sales were \$398 million. In 1951, sales of this same group amounted to \$1,200 million—the largest total on record and three times as great as in 1936. In 1939, this industry spent \$241 million for materials, fuel, and power. In 1947, the cor-

ponding figure was \$779 million. The materials used to produce protective coatings, such as resins, pigments, drying oils, cellulose derivatives, solvents, are included in these totals.

Statistics on the volume of production for protective coatings over a period of years are presented in Table 1.

Obviously, paint was the important product of the industry in 1921. At that time a great deal of paint was sold in heavy pastes (about 35% of the total) for use by painters and contractors, who did their own mixing by adding drying oil and thinners.

By 1929 there was a tremendous change and growth not only in paint production but particularly in varnishes, lacquers, and enamels. Combined production of these products was about equal to production of paint; whereas, in 1921 they amounted to only 60% of the volume of paint. This was the period when mass production was getting underway in the United States, and fast drying finishes were needed to keep the production lines moving. Nitrocellulose lacquer led the way, providing a

new type of protective coating which would dry rapidly. This development broke the bottleneck of the automobile assembly lines. It also spurred on the competitive coatings to produce fast-drying finishes as well. Production of both varnish and enamel was twice as great in 1929 as in 1921. For many years prior to this period these products had rocked along with very little growth until spurred on by the necessity of holding their markets; then, participating in the much wider market that was developing, they doubled their output in eight years' time. This is a pretty good argument for competition.

During the ten-year period from 1929 to 1939, the immediate prewar period, paste paint showed a considerable decline. Total production of paint dropped to 126,000,000 gal. from 136,000,000 ten years earlier, while the other finishes totaled 156,000,000 gal. By 1939, the varnishes, lacquers, and enamels—the coatings identified as the industrial coatings—exceeded paint production and represented 55% of the total volume of production. While lacquer continued its growth in this period, the outstanding performance was the increase in the production of enamel, due, to a great extent, to the discovery of the phthalic glyceride or alkyd type of resin in the early 1930's.

In regard to postwar data, the only census taken since 1939 was in 1947, and there has been none since that time. In this period, although paste paint continued to decline, other paints showed very large gains over prewar figures, production being up 75% from 1939 and reversing the trend of the previous decade. Again in this period, the industrial-type finishes continued to grow, showing a total production of 269,000,000 gal., a gain of 72% in the same period.

To summarize these statistics covering 25 years of this industry, production of paint has increased threefold in this time; in contrast, the production of other coatings—varnish, enamel, and lacquer—was six times as great in 1947

TABLE 1.—PROTECTIVE COATINGS PRODUCTION

	1947	1939	1929	1921
(millions of gallons)				
Paste paint .....	11.7	18.2	27.0	27.0
Ready-mixed paint .....	212.4	108.0	109.0	48.0
Total paint .....	224.1	126.0	136.0	75.0
Varnish .....	82.0	59.6	56.9	29.6
Lacquer .....	92.8	51.8	43.0	1.4
Enamels .....	94.8	44.8	29.2	14.4
Total other coatings .....	269.6	156.2	129.1	45.4

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C. W. Berl

as in 1921. Production data shown here have been very much condensed for simplification, and the great growth in industrial coatings has been stressed; however, this may give the wrong impression insofar as paint is concerned. The value of the paint products of the industry in 1947 was \$570 million; and if this segment of the industry has not shown the same rate of growth as has the industrial-coatings segment, it still represents about one-half of the total value of the products of the entire industry.

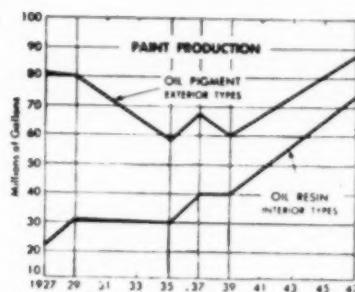


Fig. 1.

There are many different types of paint, but two types have been predominant in this period. The oil-pigment coatings, consisting of pigments ground in drying oils as the basic ingredients, are the exterior paints. The oil-resin paints, in which alkyd resins, or drying oil and resin combinations, i.e., varnish, are the basic ingredients, are essentially the base of interior paints. These two types in terms of value in 1947 accounted for 70% of all paint production. The exterior paints, which include the paste paints, were first reported separately by volume in the census data for 1927, at 82,000,000 gal. In 1947, the total was 86,000,000 gal. In the intervening years, the volume of this class of product went considerably below the 1927 level. It is obvious, based on these statistics, that this class of product has lagged behind, considering that in this period population increased considerably and construction activity was at high levels. The picture is quite different for the oil-resin or interior types of paint. Production of these products in 1927 amounted to 23,000,000 gal.; but in 1947, the total was 73,000,000 gal. Where the ratio of exterior to oil-resin paint was 3 to 1 in 1927, by 1947 it was about 1 to 1.

Another class of paint that has become important in recent years, and that because of recent developments appears headed for higher levels, is the water-thinned or water-type paint. The statistics presented above did not include this product. In the prewar years these types accounted for a very small proportion of the total. In the 1939 census,

water paints represented about 5% of the value of all paint produced, but in 1947, this had risen to about 9%, owing to the development of the resin-emulsion types of water paint, which in the war years and later became quite popular. These paints represented a volume of about 25,000,000 gal. in 1947. Since that time, this class of product is on the way to being supplanted by the new styrene-butadiene latex paints, which have achieved great popularity in a very short time and appear to be headed toward much higher volume.

The purpose of this review so far has been to secure a background and understanding of the long-term trends that exist in this industry. Knowledge of these trends can be very useful to the chemical manufacturer supplying the industry. He will find out where the greatest field for growth exists and will schedule research and development work accordingly.

Methods of determining the various raw-material requirements of this industry, on the other hand, is the phase of greatest interest to the chemical industry. One of the most satisfactory methods for determining the volume of materials required in the manufacture of any product is to estimate quantities through production data such as have been reviewed and then to balance data obtained in this manner against whatever statistical data are available on the raw material in question. It is possible to analyze many markets in this manner. One which comes to mind concerns the volume of cellulose consumed in the manufacture of rayon, acetate, film, plastic, etc. There are excellent statistics on production of these items to which may be applied factors to obtain estimated cellulose consumption from the production data. These results, however, must balance with corresponding data on production or consumption of dissolving pulp. If they do not balance, something is wrong. When they come into balance, a correct analysis has been secured.

Such procedures in recent months have become increasingly popular. Recent shortages of such important chemical materials as benzene, naphthalene, chlorine, etc., have led to exhaustive end-use studies by market analysts, which have appeared regularly in the chemical journals.

In an industry such as paint, varnish, and lacquer, it is extremely difficult to employ such techniques. What must be done, in effect, is to take 500,000,000 gal. cans of product and say, for example, that each can contains  $x$  lb. of drying oil,  $x$  lb. of pigments, solvent, etc. Then all this must be multiplied to determine the total. Consequently a very small error per unit can lead to a very large error in appraising the entire

market. To determine the volume of some of the materials which go into coatings, however, this is the only procedure possible. Take for example mineral spirits. Techniques for analyzing the mineral-spirit content of each separate product of the industry must be worked out to be secured, and there are no other statistics to check against the findings in this case which tell, as the artilleryman would say, whether you are in the zone of probable error.

In order to estimate data for materials consumed in manufacture of protective coatings based on production data, the best approach is to separate the products of the industry into three basic chemical types: (1) drying oil—pigment, (2) oil resin—pigment, (3) nitrocellulose plasticizer.

The drying-oil pigment, or oil-paint types—normally exterior paints—are produced by grinding pigments such as white lead, titanium dioxide, zinc pigments, and others in linseed oil. The

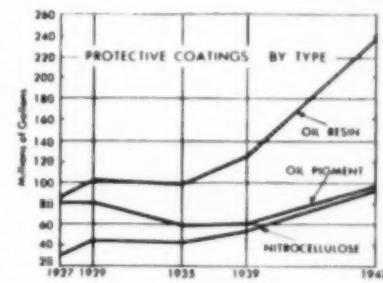


Fig. 2.

film or coating is formed through the oxidation of the oil.

Oil-resin compositions, used largely in interior paints and in industrial coatings for all kinds of service conditions, are of two types known to the paint man as alkyd and oleoresinous varnish. For the most part, either of these oil-resin compositions depends upon oxidation or polymerization of the drying-oil component to form the film or coating. This oil-resin type of finish is now the most important coating volumewise. The oil resin may be used without pigment as a clear varnish for furniture and woodwork, but it is the basic material for the manufacture of a vastly larger volume of pigmented coatings.

The third type of coating is produced by nitrocellulose in solution in combination with plasticizers. This is lacquer. The film is deposited unaltered by chemical reaction. Lacquer is used almost entirely in the industrial field for automobiles, furniture, and other assembly-line products.

Figure 2 shows that 85% of the total volume of coatings falls into one of these three basic types. Combining

all the coatings that belong in each type gives some indication of trends within the industry. This volume of oil-pigment type of coating is seen to be about where it was 20 years ago, as has already been shown. Nitrocellulose types have grown from 30,000,000 gal. in 1927 to 82,000,000 in 1947; while oleoresinous types have gone from 80,000,000 to 240,000,000 in this same period.

As Figure 2 shows, the oil-resin type of coating is the most important volume-wise; therefore, it would seem appropriate because of their great importance in protective coatings to discuss a method for determining the volume of resins consumed in the production of paint, varnish, and lacquer. Certain average formulations must be assumed, based on knowledge of each type of product, and from this can be calculated the quantities of oil-resin composition. For example, in 1947, production of interior types of paint, and of undercoats and primers, amounted to 73,000,000 gal. It can be estimated from the average formulations that must arbitrarily be accepted for these products that they contain about one-third by volume of oil-resin composition. This means a total of 24,300,000 gal. of the oil-resin base. In addition, some of the ready-mixed oil or exterior paints contain a limited proportion of oil-resin base, particularly in those types used for trim. It may be estimated that these paints contain 5,300,000 gal. of oil-resin base. Oleoresinous varnishes contain 50% oil resin and 50% thinner. Production was 56,200,000 gal. in 1947, which means 28,100,000 gal. of oil-resin content. Enamels contain 40% oil-resin, which means an estimated 38,600,000 gal. of oil-resin. Other types of paint, such as marine, metallic, traffic, etc., are estimated in 1947 to contain 16,900,000 gal. of oil resin. This gives a total of 113,200,000 gal. of oil-resin content.

In this particular instance, the method would ordinarily be to calculate the quantity of resin present in this quantity of oil-resin composition on an arbitrary basis, as, for example, on the basis of 2 lb. of resin to 6 lb. of oil, or 3 lb. of resin to 5 of oil, based on a knowledge of the formulations used. To this resin figure would be added resins used in other coatings. The total resin figure procured in this manner should then be compared with other statistics covering resin production and consumption in protective coatings in that same year.

In the case of resins, this procedure cannot be followed exactly because the production of some alkyd resins, as reported in the statistics, includes oil as well as resin. It has been estimated that 25,000,000 gal. of the oil-resin compositions are alkyds (based on an

analysis of the resin statistics) and contain oil in their composition. This accounts for 209,000,000 lb. of resin. The remaining 88,000,000 gal. of oil resin are estimated to contain (based on average formulation) 2.5 lb. of resin/gal., a total of 220,000,000 lb. of resin. In addition, there are 45,000,000 lb. of resin in lacquers and other varnishes (resin-solvent types), an estimated 50,000,000 lb.; also, in resin-emulsion paints an estimated 17,000,000 lb. The total amounts to 541,000,000 lb. of resin, which have been calculated from the production data.

Before this figure is compared with resin statistics taken from other sources some general information on protective-coating resins is necessary. The materials that form the basic elements for these resins are synthetic products such as phthalic glycerine (alkyd), phenol formaldehyde, urea formaldehyde, styrene resins, and others. These products are often combined with rosin to form rosin esters or are modified by rosin esters. Also, rosin and tall oil are used to some extent, and natural resins, imported products such as dammar and copal, which have a long history in the protective-coating field.

The United States Tariff Commission in its annual report on production and sales of synthetic organic chemicals for 1947 reports that production of all types of synthetic resins produced for protective coatings in that year amounted to 453,000,000 lb. The Department of Agriculture statistics, showing consumption of rosin by paint and varnish manufacturers in 1947, indicate a consumption of 59,000,000 lb. In addition, a consumption of 25,000,000 lb. of tall oil would represent about 50%, or 12,500,000 lb. of additional rosin. Imports of natural resins, amounting to 10,000,000 lb., can be considered as representing the quantity of these products consumed. By utilizing, therefore, all the statistics pertaining to resins and rosins for protective coatings, the following data are secured:

	Millions of lb.
Synthetic resins .....	453.0
Rosin .....	59.0
Natural resins .....	10.0
Tall oil .....	12.5
	<hr/>
	534.5

TABLE 2.—ENAMEL PRODUCTION

Product and state	No. of establishments	Quantity (gal.)	Value
Enamel .....	485	18,908,607	33,106,479
California .....	64	1,575,743	2,909,929
Florida .....	4	1,372	2,385
Georgia .....	5	124,866	168,754
Illinois .....	37	2,048,221	3,575,527

The figure for total resin consumption in this industry has been arrived at by two different routes. In one instance certain assumptions were made as to resin content based on production. In

the other instance the Tariff Commission gave figures for production of synthetic resins for protective coatings, to which were added figures for rosin, tall oil, and natural resins. The figures of the two methods are only 7,000,000 lb. apart, less than 2%.

It may be felt that the amount of labor involved in analyzing production data, as exemplified by this study of resins, is not justified if there are sufficient data on resin consumption in protective coatings already supplied. By use of such data, a company's over-all position can be measured satisfactorily. Why worry about the rest?

This may be true in some cases, but ordinarily it is not. The resin producer does not manufacture a product that answers all purposes. It has special applications in some particular protective coating, and it is here that the analysis of production data pays off. For a resin that has special advantages to the producer of enamels, for example, it is possible to secure the census separate data showing production of enamels by state. (A partial tabulation from the 1939 census is shown in Table 2.) Here are shown the number of enamel producers in each state, the volume of production, etc. Here is the market for anything to be sold to the enamels producer. Such data as these are essential in planning sales campaigns, plant locations, budgets (advertising), and all the usual operations accompanying product development and distribution. From such data can be built up geographic quotas for a sales force, and without them there would be no way of appraising the particular market that must be reached.

In this short paper an attempt has been made to outline a broad basis for attacking the problem of industry analysis by taking one industry and showing trends that have occurred within it for a period of years and also by demonstrating how data on consumption of materials by this industry can be secured.

One interesting result of working with the statistics is that the more one uses them, the more one gains an insight into how to use them. New thoughts keep cropping up to offer new possibilities and to show relationships that can be used advantageously perhaps

for supplying current data where none exist or for the purpose of forecasting. There is, however, no easy road in chemical market research. To learn, one must get in there and dig.

# Finding the Facts and Figures

Richard M. Lawrence and Jonathan H. Sprague

In carrying out market research functions as outlined in the present series, it is necessary to get a great variety of data, both statistical and nonstatistical, on production, consumption, imports, exports, expansion programs, operations of customers, etc. Some of the best sources of these data, both government and private, will be discussed in this paper. Government publications are particularly important, for because of tax support it is often possible to purchase a survey costing \$25,000 or more for 25 or 50 cents. A bibliography of published sources is appended.

The sources will be considered in the order that they might be consulted if an actual survey were being made: (1) company records, (2) published surveys, (3) statistical compilations, (4) basic data sources, (5) special sources, (6) personal contacts.

**Company Records.** The first place to check is one's company records. Days of hard work can be saved if someone else has already done the job or a similar one. Sales reports, sales-analysis studies, I.B.M. cards, clippings files, or the little black book of the salesman himself may provide the needed information. Or possibly it is the purchasing department or the traffic department that has the data. All should be checked.

**Surveys.** Assuming that more data are needed, the next step is to see whether a similar survey has already been published. Some of the best survey sources are as follows.

Chemical Engineering and also Industrial and Engineering Chemistry have excellent annual reviews of the field. These together with Chemical Week and Chemical and Engineering News have also made detailed surveys, especially in the fields of basic chemicals, sulfur, ammonia, benzene, and ethylene, to mention a few.

Summaries of Tariff Information is a U. S. Tariff Commission series contain-

ing surveys of a wide range of chemicals, including many of the lesser compounds. Although three to four years old, it is a starting point for studying almost any product.

The Minerals Yearbook and Department of Agriculture Surveys are discussed later under Basic Sources. Faith, Keyes and Clark's book "Industrial Chemicals" presents short surveys on more than 100 chemicals. The Chemical Market Report of Foster D. Snell, Inc., is a classified monthly abstract service covering commercial items in more than 100 chemical industry publications. The National Industrial Conference Board is another valuable source of reports on the chemical and other industries.

**Statistical Compilations.** In the absence of surveys, the next best time saver is the use of existing compilations. The Manufacturing Chemists Association publication Chemical Facts and Figures is a comprehensive statistical handbook of the industry. Trade associations in other fields such as petroleum, paint, fertilizer, and paper have similar handbooks.

The Stanford Research Institute's Chemical Economics Handbook is a comprehensive service with statistics and charts on all chemicals of commercial importance and also data on hundreds of companies. Industrial Marketing Magazine, annual market data and directory number, includes brief statistical reviews of the principal industries.

The monthly Survey of Current Business publishes thousands of statistical series with comparative figures for the twelve preceding months. The annual supplements have data for the last ten or twenty years.

The Statistical Abstract of the United States, as the name implies, presents condensed figures on commodities and industries, as well as on population,

labor, education, finance, and virtually every field of statistics.

**Basic Data Sources.** These key sources, the heart of any literature survey, are listed in Table 1. As will be noted, they are broken down by the principal types of data provided, five on production, one on foreign trade, and two on prices.

TABLE 1.—BASIC DATA SOURCES

Production
Census of Manufactures
Facts for Industry
Synthetic Organic Chemicals
Minerals Yearbook
Agricultural Statistics
Imports & Exports
Census Foreign Trade Reports
Prices
Oil Paint & Drug Reporter
BLS Wholesale Price Index

**Manufactures.** For production statistics and other manufacturing data, the primary publication is the Census of Manufactures. This document has market data of interest to equipment and power engineers as well as to chemical-production men. It covers "all industry" in 450 groups, including 55 in the chemical-process industries, and 9 in chemicals and allied products, as listed below:

Industrial Inorganics	Drugs
Industrial Organics	Soap
Wood Chemicals	Paint
Vegetable Oils	Fertilizers
Miscellaneous	

For each of these industry groups, such data are given as number of establishments, plant size, employment, raw-materials cost, fuel and power consumption, inventories and plant expenditures. And the data are made even more useful by state subtotals. For hundreds of individual chemicals, Census of Manufactures gives production figures, and for certain important products, such as caustic, it breaks them down by process and thereby permits engineers to analyze trends.

Unfortunately, the Census of Manufactures is issued only about every five years. The last one was for 1947. To fill in this gap, there are the Census Facts for Industry reports, a series of production reports some monthly, some quarterly, and some annual. Of the sixty-three series six are in chemicals:

Inorganic Chemicals
Superphosphates
Paints, Varnish, Lacquer & Filler
Gelatin
Animal Glue
Wood Charcoal

The inorganic chemicals report, perhaps the most important, gives monthly production data on over fifty chemicals, with breakdown by process on the leading ones. The yearly report covers a much wider list and in the case of sulfuric acid gives a regional breakdown.



J. H. Sprague

Richard M. Lawrence, of Monsanto Chemical Co., was the chairman of the chemical market research symposium. His biography appeared in the October issue, page 528.

Jonathan H. Sprague is with the development department of the Freeport Sulphur Co., New York. He joined the company in 1952 after eight years with Monsanto Chemical Co. in the Merrimac Division and Washington office, where he was engaged in market research problems. Mr. Sprague received the B.S. and M.S. degrees in chemical engineering from Massachusetts Institute of Technology and in 1947 the M.B.A. from Harvard Business School.

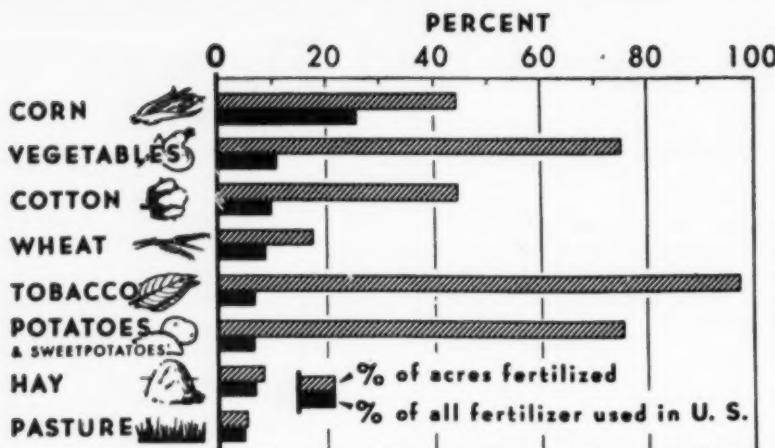


Fig. 1. Use of fertilizer on selected crops, 1947.



U. S. Department of Agriculture

Fig. 2. Wood-preserving plants in the United States.

The Tariff Commission has two free Facts for Industry series, one covering seventy-five organic chemicals, the other covering forty-one plastic materials.

**Organic Chemicals.** For more comprehensive coverage of synthetic organic production, there is one of the best government publications, the Tariff Commission's Synthetic Organic Chemicals, usually available six or eight months after the end of the year. Preliminary bulletins on the individual groups, however, are released promptly, starting in the spring.

This publication lists annual production and sales statistics for many hundreds of individual organic chemicals. The principal groups covered are:

Raw Materials	Dyes
Intermediates	Rubber Chemicals
Plastics	Drugs
Plasticizers	Detergents
Insecticides	Others

Statistics may be found here for every organic chemical in these categories where publication will not reveal the operations of individual companies. The confidential figures are grouped in special subtotals to hide their identity. The

second half of this report is almost equally valuable; it lists all 6,000 synthetic organics made in the United States, together with their manufacturers.

**Minerals.** In the minerals field is another of the best primary market-research sources, the Minerals Yearbook, with data on production, sales, uses, prices, and foreign trade. The text of the yearbook discusses trends and developments and also activities of leading firms in the field. There are sixty-five chapters covering metals, ores, fuels, and building materials, including such products as phosphate rock, titanium, bauxite, carbon black, coke and coal chemicals (benzene and naphthalene), sulfur, fluorspar, and potash.

Again time lag presents a problem. The 1949 Yearbook became available in October, 1951. The individual chapters, however, are issued as preprints as soon as written, thus becoming available sometimes as much as a year before the book is released.

In addition, the Bureau of Mines puts out two free series, which contain preliminary data. One is entitled Mineral

Market Reports, each issue of which is published just as soon as it is prepared. The other is a series of weekly, monthly, and quarterly Mineral Industry Surveys. Data given are similar to those of the other publications.

**Agriculture.** Here is a market becoming more important every day, especially to manufacturers of pesticides and fertilizers, to whom the type of data offered in Figure 1 is essential.

The basic source book for this field is the annual Agricultural Statistics, comprised of hundreds of series. It has data on individual crops—production acreage, yields, and prices—and on such derived materials as lard, vegetable oils, turpentine, and margarine. There are 750 pages of fine-type statistical tables, many of them broken down by states.

In addition to these records of the past, there are numerous publications looking into the future. Persons concerned with agricultural raw materials may be interested in the Fats and Oils Situation or the Naval Stores Report. Fertilizer manufacturers may be interested in the Fertilizer Situation, antibiotic and choline manufacturers in the Poultry and Egg Situation. For pesticide manufacturers there are other outlook publications. Perhaps the best over-all publication is the Production Goals Program Preliminary Handbook. This has acreage goals by states for different crops as well as the outlook on livestock and poultry production, fertilizer, etc. And for those who prefer graphic presentation to statistics, there is an annual publication of Outlook Charts. From time to time are issued special reports bearing such titles as "Spraying and Dusting Major Field Crops" and "Fertilizer and Lime Used on Crops and Pasture 1947."

**Consumption.** Data are scarce for answering the questions where does the product go? and in what quantities? There are no general sources. In a few cases, however, actual consumption data are available. The most noteworthy of these is the report on ethyl alcohol published by the Alcohol Tax Unit. This gives a complete end-use pattern. The Census of Manufactures has some limited consumption data, as do the Minerals Yearbook and the Department of Agriculture publications, especially in the fertilizer field, where consumption is given by state. There were also some wartime end-use patterns published for 1944 and 1945. These complete data, however, are the exception rather than the rule. The standard method is to take production figures for the consuming industries and convert them into requirements for the chemicals in question, for example conversion of tire production into carbon black requirements or conversion of paper production into size.

For many processes chemical requirements per unit of production can be found in the literature.

**Foreign Trade.** Import statistics are essential for checking not only foreign competition but also foreign sources of chemical raw materials. The official figures are presented in the Census Bureau's Report FT-110. This report comes out monthly and for hundreds of products gives quantity and dollar-value figures, both broken down by country of origin. For instance, the benzene imports for 1950, given in Table 2, show that the principal source was the United Kingdom and also reveal some interesting differences in average prices paid. The FT-110 report is arranged by com-

**Special Sources.** The first two sources, relatively new (see Table 3), result directly from the mobilization program and cover, respectively, government procurement and industrial expansion programs. These are particularly important; for unlike most previous publications discussed, which merely recorded the past, these point out markets both now and in the future.

Consolidated Synopsis of Procurements is a daily summary of bid-invitation announcements and contract awards. The bid invitations indicate possibilities for millions of dollars of direct sales to the government. The award information shows how subcontracts are allotted and just which companies to contact for

details can be found. Chemical and Engineering News and Chemical Week have also been summarizing these data.

**Trade Directories.** This discussion has been dealing largely with industry data. Data are also needed on individual companies—customers and competitors.

First, with regard to names of customers and competitors, there are trade directories. Besides the familiar Chemical Week Buyers Guide Book and the Oil, Paint, and Drug Reporter Green Book, there is, for more comprehensive coverage, including detail on plant locations, the Modern Plastics Encyclopedia and the McGraw-Hill Directory of Chemicals and Producers. And there are equally useful directories in other fields, directories that can often provide ready-made customer lists. For example, in the paper field, Lockwood's Annual gives data on mills by states, including types of paper, equipment, capacity, and key men.

Trade-association-membership directories may also provide lists of companies that are prospective customers. The names of trade associations can be obtained from an excellent government book, National Associations of the United States. Also, there are other government publications. The Tariff Commission's Synthetic Organic Chemicals Report lists the producers of every organic chemical made in the United States. Lists in the Bureau of Mines reports may also indicate customers. The C.A.A. can provide pesticide manufacturers and other interested people with a list of every licensed aircraft sprayer in the country. Figure 2 illustrates the type of data to be derived from government sources—a ready-made map of all customers for wood preservatives.

modity code number instead of alphabetically, necessitating the index, Schedule A, which also gives the tariff rate. Comparable publications are available for exports (FT-410 and Schedule B).

Time lag in issuance of these reports is about two months. Data can be obtained a month earlier from the code runs available at the Commerce Department in Washington. These runs are doubly useful in that they supply data broken down by customs district, which may give a lead on where the material is going. The latter figures do not appear in published form.

**Price.** Two types of prices may be needed, spot prices or a series of historic prices upon which to project future trends.

The best sources for spot prices are the trade journals. In the field of chemicals, the most complete quotations are in Oil, Paint and Drug Reporter. Also, Chemical and Engineering News has been reproducing one quarter of this list each week. If average prices are adequate for research needs, they may be computed from the publications mentioned earlier, which give data both in quantity and value. If a price is needed which is not in one of the publications, the purchasing department can doubtless secure it.

Noteworthy for giving historic price series are the publications of the Bureau of Labor Statistics. Of primary interest to engineers may be the wholesale price index with its breakdown by commodity groups. This is presently being modified to change the base from 1926 to 1947-49 and to include the effect of new materials such as plastics.

TABLE 2.—BENZENE IMPORTS—1950

Country of Origin	Quantity (1000 gal.)	Value (\$1,000)	Average Price (cents/gal.)
Germany	470	230	49
Belgium	350	160	46
Poland	4,790	1,180	25
Canada	1,270	340	27
Czechoslovakia	970	240	25
United Kingdom	15,440	4,420	29
Total	23,290	6,570	28

Note: Average prices computed.

TABLE 3.—SPECIAL SOURCES

1. Consolidated Synopsis (Procurement)
2. Defense Production Record (Expansion)
3. Trade Directories (Customers, competitors)
4. National Associations of U.S.
5. Financial Directories
6. Corporate Annual Reports; Prospectuses
7. Market Research Sources (bibliography)

further sales. There is no mail distribution of the daily synopsis, but it is reportedly distributed to several thousand pickup points in the United States: regional Commerce Department offices, chambers of commerce, and other business groups. Secondary sources for this information are the U. S. Government Advertiser, a private weekly compilation, and a weekly Bureau of Labor Standards summary of contract-award information. The latter is less detailed on product description but has the advantage of being classified.

Defense Production Record is a summary of mobilization data from the daily press releases of the National Production Authority and Defense Production Administration. These are particularly important to equipment company men for they include data on national goals for expanded production capacity. One such, for example, is the proposed phthalic anhydride capacity expansion by 1955 to 368 million pounds from 228 million January 1, 1950. These releases even indicate actual equipment customers in their listings of tax amortization grants. The Certificate of Necessity award lists give company name, plant location, product, and the dollar value of the expansions, which engineers can convert into estimates of additional capacity. Defense Production Record not only summarizes these data, but also cites the press releases in which further

**Financial Data.** For a quick picture—sales, profits, plant locations, general products, key executives, etc.—there are several good financial references, Moody's Industrials, Standard and Poor's, and Dun & Bradstreet Reports. However, engineers, especially equipment men, may be more interested in plant expansion plans. For these, write to the various companies for their annual reports. These in almost every case compare the coming year's plant expenditure with the past and in many cases tie this down to specific expansions. In addition, some give data on research expenditures. The most detailed data on company expansion plans are provided by underwriters' prospectuses accompanying new stock issues, for the S.E.C. requires companies to tell where and how the new money will be used. Copies may be obtained from a stockbroker.

**Indexes.** Chemical market research has an extraordinary range of interests, at times requiring specialized data on almost every type of industry. To locate the hundreds of specialized sources, a

knowledge of indexes is necessary. Market Research Sources, a government publication for this purpose, was brought up to date in 1950 and is an excellent starter. Chemical Industries published a long series of articles in 1946 and 1947, which described and listed hundreds of sources for chemical market research. There are catalogs of the various government agencies besides those already listed. The Survey of Current Business, presenting thousands of statistical series with source citations, is another valuable check list of sources. Although old, the Commerce Department's Chemical Statistics Directories, covering 1945 to 1947 only, are still useful for index work.

**Contacts.** Market research information goes far beyond statistics. Its broad scope includes data on methods of use, competition from substitute products and alternate processes, the future of taxes and government regulations, and all other factors which affect the competitive situation and the company's position in the market picture. In every worthwhile market survey the literature study must be supplemented by field work to learn what is behind the figures and where the trends are leading. Industry contacts who know and trust him are among a market researcher's most valuable assets. Some of the best contacts are:

1. The potential customer's purchasing agents and research directors, who can give their requirements outlook over both the short and long term.
2. Suppliers of raw materials, whose sales managers and directors of development will wish to aid a new project.
3. Trade-journal editors, skilled interpreters of industrial situations.
4. Government experts, such as N.P.A. commodity specialists, mostly technical men, one of whose principal functions is to analyze the outlook for various chemicals to determine whether expansion is justified. (They cannot reveal confidential data, but they can give a good over-all picture.)
5. Trade association executives with both broad and detailed knowledge of their industries.

Despite all the help outlined above, however, there is no simple solution to chemical market research problems. The researcher must roll up his sleeves, get out his slide rule, and apply his technical know-how to the data he painstakingly accumulates.

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###### Foreign Commerce Yearbook, \$2.25

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###### Carbon black (M)

###### Coke and coal chemicals (M)

###### Fluorspar (Q)

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Government publications for which recent prices are quoted should be obtained from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Requests for other government publications should be sent to the publications distribution section of the agency in question. The Bureau of Mines address is 4800 Forbes Street, Pittsburgh, Pa. Address of the other agencies is Washington 25, D. C.

\* Compiled by Martha E. Hughes, Monsanto Chemical Co.

(This is the final paper in the Chemical Market Research series, which began in the October issue.)

# ANNUAL THESIS INDEX

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## EDITOR'S NOTE

This is "C.E.P.'s" second classification of the year's Ph.D. theses. The comments and reactions received last year on the new feature have been more than favorable. Again, it is suggested that in following some specific subject, more than one title heading be consulted since several operations may be under investigation but actually listed in these pages only under one heading. For instance, in a particular investigation, both heat and mass transfer and perhaps fluid flow may have received treatment. Since such a study would be listed under one heading only, it is wise to cover most possibilities in a search.

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**STUDY OF FLOODING IN PACKED COLUMNS.** Tom Brooks Metcalfe. Georgia Institute of Technology. Prof. W. M. Newton. 74 pp. Two copies available in library. Abstract available separately. (June, 1952.)

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## Heat Transfer

**BED-WALL HEAT TRANSFER COEFFICIENTS IN A FLUIDIZED SYSTEM.** Octave Levenspiel. Oregon State College. Prof. J. S. Walton. 103 pp. One copy available in library. (1952.)

**CONVECTIVE HEAT TRANSFER FROM A GAS STREAM AT HIGH TEMPERATURE TO A CYLINDER NORMAL TO THE FLOW.** Stuart Winston Churchill. University of Michigan. Prof. J. C. Brier. 170 pp. One copy available in general library. Microfilm 1½ cents a page. Abstracts and conclusions available separately from University Microfilms. (1952.)

**EFFECTS OF FLUID PROPERTIES ON BOILING COEFFICIENTS.** John Earle Myers. University of Michigan. Prof. D. L. Katz. 138 pp. One copy available in general library. Microfilm 1½ cents a page. Abstracts and conclusions separately available from University Microfilms. (1952.)

**HEAT AND MOMENTUM TRANSFER BETWEEN A SPHERICAL PARTICLE AND AIR STREAMS.\*** Y. S. Tang. University of Florida. Prof. J. M. Duncan and Prof. H. E. Schweyer. 105 pp. (February, 1952.)

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**RADIANT HEAT TRANSFER FROM SUPERHEATED STEAM.\*** Henry Jackson Ramey, Jr. Purdue University. Prof. J. M. Smith. 266 pp. Photostats—negative 30 cents, and positive 60 cents a page, respectively; microfilm 5 to 10 cents a page. (June, 1952.)

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**THERMAL CONDUCTIVITY OF LIQUIDS.\*** Tadeusz K. Slawek. University of Pennsylvania. Prof. M. C. Molstad. 152 pp. Two copies available in Department of Chemical Engineering. Abstract and conclusions available separately. (June, 1952.)

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## Ion Exchange

**RATES OF ALCOHOLYSIS AND DIFFUSION IN ION-EXCHANGE RESINS.\*** George Edward Barker. University of Michigan. Prof. R. R. White. 132 pp. One copy available in general library. Microfilm 1½ cents a page. Abstract and conclusions available separately from University Microfilms. (1952.)

**RECOVERY OF METALS FROM DILUTE BRASS MILL.\*** Peter Frank Hagerty. Yale University. Prof. Harding Bliss. 477 pp. One copy available in Sterling Memorial Library. Abstract and conclusions available separately. (June, 1952.)

\* Work continuing.

## Kinetics

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**CATALYSIS FOR HYDROCARBON SYNTHESIS,\*** Louis George Smith. Illinois Institute of Technology. Prof. V. I. Komarewsky. 102 pp. One copy available in library. (January, 1952.)

**CONTINUOUS FIXED BED CATALYTIC HYDROGENATION OF COTTONSEED OIL,** Edgar W. Miller. Case Institute of Technology. Prof. R. L. Savage. 183 pp. Two copies available in library. Photostat 25 cents a page. (1951.)

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**FACTORS AFFECTING THE ACTIVITY OF MOLYBDENE-ALUMINA CATALYST,\*** Charles J. G. Rudershausen. University of Wisconsin. Prof. C. C. Watson. One copy available in library. Photostat 5 cents a page; microfilm 15 cents an exposure. (June, 1952.)

**HIGH-TEMPERATURE VAPOR-PHASE CRACKING OF HYDROCARBONS,** Henry Robert Linden. Illinois Institute of Technology. Prof. R. E. Peck. 109 pp. One copy available in library. (June, 1952.)

**HYDROLYSIS OF CELLULOSE IN CONCENTRATED HYDROCHLORIC ACID SOLUTION,\*** Roderick Chung-Chao Shen. University of Washington. Prof. J. L. McCarthy. 75 pp. One copy available in library. Photostat 30 cents a page; microfilm 3 cents a page. (June, 1952.)

**KINETICS OF THE CATALYTIC OXIDATION OF NITRIC OXIDE BY CARBON,\*** Mokko Narasingha Rao. University of Wisconsin. Prof. O. A. Hougen. 135 pp. One copy available in library. Photostat 5 cents a page; microfilm 15 cents an exposure. (June, 1952.)

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**KINETICS OF POWDERED COAL GASIFICATION,** Robert M. Busche. Washington University. Prof. W. P. Armstrong. 273 pp. Two copies available in engineering library. (June, 1952.)

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**NEW TOOLS FOR DETERMINING THE STAGE OF POLYMERIZATION OF PHENOL-FORMALDEHYDE CONDENSATES,\*** George A. Sofer. Massachusetts Institute of Technology. Prof. E. A. Hauser. Photostats and microfilms available from Hayden Library, M.I.T. (September, 1952.)

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**VAPOR PHASE DEHYDRATION OF AN ALCOHOL AND ETHER,\*** Robert Martin Longer. Yale University. Prof. C. A. Walker. 185 pp. One copy in Sterling Memorial Library. Abstract and conclusions available separately. (June, 1952.)

## Mass Transfer

**CONTINUOUS FLOW STIRRED TANK REACTORS—SOLID-LIQUID SYSTEMS,\*** Robert V. Mattern. University of Minnesota. Prof. E. L. Piret. 43 pp. Unavailable. (March, 1952.)

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**MASS TRANSFER BETWEEN LIQUID DROPS AND A CONTINUOUS LIQUID PHASE IN A COUNTERCURRENT FLUIDIZED SYSTEM,\*** Charles L. Ruby, Jr. Princeton University. Prof. J. C. Elgin. 65 pp. One copy available in library. Abstract and conclusions available separately. (June, 1952.)

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## Phase Equilibria

**DETERMINATION AND THERMODYNAMIC CORRELATION OF VAPOR-LIQUID EQUILIBRIUM DATA FOR THE WATER-ACETIC ACID SYSTEM,** Salvatore John Silvis. Polytechnic Institute of Brooklyn. Dr. D. F. Othmer. 191 pp. One copy available in Chemical Engineering Office. (June, 1951.)

**ON THE VAPOR-LIQUID EQUILIBRIA OF NON-IDEAL SYSTEMS,\*** Stephen Yerazunis. Rensselaer Polytechnic Institute. Prof. H. H. Steinhausen, Jr. 68 pp. One copy available in library. (June, 1952.)

**PHASE EQUILIBRIA IN THE 1-BUTENE-WATER SYSTEM AND THE n-EUTANE-WATER SYSTEM,\*** Warren Booth Brooks. University of Texas. Prof. J. J. McKetta, Jr. 148 pp. Two copies available in library. (May, 1952.)

**PHASE EQUILIBRIUM IN SYSTEMS WITH SUPER-CRITICAL ETHYLENE,\*** David B. Todd. Princeton University. Prof. J. C. Elgin. 122 pp. One copy available in library. Abstract and conclusions available separately. (November, 1951.)

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**TWO-PHASE AND THREE-PHASE EQUILIBRIA IN THE SYSTEM: CARBON DIOXIDE-METHANE,\*** Horold George Donnelly. University of Michigan. Prof. D. L. Katz. 218 pp. One copy available in general library. Microfilm 1½ cents a page. Abstract and conclusions separately available from University Microfilms. (1952.)

**VAPOR-LIQUID EQUILIBRIA IN THE BINARY SYSTEMS n-BUTANE-METHANOL AND 1-BUTANE-METHANOL,\*** William Joseph Boyne. Purdue University. Prof. T. C. Doody. 98 pp.

\* Work continuing.

One copy available in library. Photostats—negative and positive 30 cents and 60 cents a page, respectively; microfilm 5 to 10 cents a page. (June, 1952.)

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### Thermodynamics

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**PHASE EQUILIBRIA AND THERMODYNAMICS OF SOLUTIONS.** Jay H. Ashley. Northwestern University. Prof. George Martin Brown. 82 pp. One copy available in Technological Institute Library. (August, 1952.)

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### Ultrasonics

**EFFECT OF ULTRASONIC IRRADIATION ON THE SPECIFIC REACTION RATE CONSTANT IN THE ACID HYDROLYSIS OF ETHYL ACETATE.** Walter C. Gray. Virginia Polytechnic Institute. Prof. F. C. Vilbrandt. 470 pp. Loan can be arranged with library. (June, 1952.)

### Miscellaneous

**DEGREASING EVALUATION TESTS FOR METALS PRIOR TO ELECTROPLATING.**\* Edward Basil Saubestre. Columbia University. Prof. H. B. Linford. Withheld until May 23, 1954. (June, 1952.)

**DESORPTION OF HYDROCARBONS FROM AN UNCONSOLIDATED SAND.** Charles W. Oxford. University of Oklahoma. Prof. R. L. Huntington. 113 pp. Three copies available in library. (1952.)

**DISCHARGE FLOW PATTERNS OF TURBINE-TYPE MIXING IMPELLERS.**\* John Peter Soehs. Illinois Institute of Technology. Prof. J. Henry Rushton. 85 pp. One copy available in library. (June, 1952.)

**ENERGY-NEW SURFACE RELATIONSHIP IN THE CRUSHING OF SOLIDS. VI. EFFECT OF TEMPERATURE.**\* Norman F. Schulz. University of Minnesota. Prof. E. L. Piret. 107 pp. Unavailable. (September, 1951.)

**FORMATION OF CHEMICAL FILM DEPOSITS ON ALUMINUM SURFACES.** Robert V. Andrews. A. & M. College of Texas. Prof. P. G. Murdoch. Filed with A.E.C. Secret Documentation HW 23494 dated Feb. 8, 1952. Available to authorized persons. Table of contents, lists of tables and figures, available at college. (May, 1952.)

**HYDROCARBON SEPARATIONS BY VAPOR-LIQUID EXTRACTION.**\* Robert G. Geier. Pennsylvania State College. Dr. M. R. Fenske. 242 pp. One copy available in library. (January, 1952.)

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**PREFLAME OXIDATION OF HYDROCARBONS AND DETONATION.**\* Basil J. Reitzer. Northwestern University. Prof. G. G. Lamb. One copy available in Technological Institute Library. (August, 1952.)

**SOME VARIABLES AFFECTING THE RATE OF CRYSTAL GROWTH IN AQUEOUS SOLUTIONS**

(POTASSIUM ALUM).\* Joseph Anthony Palermo. Syracuse University. Prof. C. S. Grove, Jr. 234 pp. One copy available in library. (June, 1952.)

**SPECTROPHOTOMETRIC STUDIES:** 1. **FERRIC THIOCYANATE;** 2. **FERRIC TANNATE.** Harold E. Corwin. Syracuse University. Prof. C. S. Groves, Jr. 256 pp. One copy available in library. (September, 1952.)

**STUDY OF THE FORMATION OF GAS BUBBLES FROM HORIZONTAL CIRCULAR SUBMERGED ORIFICES.**\* Leon Davidson. Columbia University. Prof. Erwin H. Amick, Jr. One copy available in library. Photostat 10 cents a page; complete microfilm \$2.76 from University Microfilms. (November, 1951.)

\* Work continuing.

## LETTERS TO THE EDITOR

### Selling Yourself Overemphasized?

Sir:

Numerous articles have been published to emphasize the importance of correct and good English in professional work and as a means to advancement. Since a new crop of engineering graduates enters industry each year, good advice can stand repeating and for this reason the article by John A. Field in the October issue of your magazine (see p. 482) is welcome. This article should be recommended to all young engineers as it tells why and how success is achieved in professional work in terms of reaching positions of responsibility and high pay.

However, it seems to me, that the author puts too much emphasis on the idea of the individual's selling himself to his superiors as a sure way of achieving success. The young engineer is told definitely that the burden of proof of ability is his and his only. Perhaps this attitude can be defended in the name of competition and rugged individualism, but is it in the best interest of all concerned to let ability and talent go unnoticed in a given organization simply because the individual fails to attract the attention of his superiors?

There are many people of ability who may not be considering top positions of responsibility, but they will perform very well once they are discovered and "drafted." As a matter of fact, such men may not even be aware that they have natural gifts which would make them highly valuable to the organization in higher positions. An oriental proverb says aptly: "He who knows and knows not that he knows is asleep, wake him." Accidental discovery of talent is not a reliable way of filling positions of responsibility, and for this reason management also should follow a systematic program of talent scouting.

M. G. Larian  
East Lansing, Mich., Nov. 6, 1952

### Desideratum—Simple Technical Writing

Sir:

I was interested in the article by Howard M. Mathis in the November Chemical Engineering Progress titled "A Plea for Simplicity." It seems to me his basic idea is good—that we can improve technical writing by making it simpler. However, I would take exception to the first of his suggested guideposts—*Try to write as you would speak.*

One reason for not writing as you would speak lies in the inherent finality of the written word. In speech an opportunity is present for repeating yourself, if necessary, to make your meaning clear. The reaction of the listener often gives a clue as to whether or not further explanation is necessary, but the writer can't predict the extent of the reader's understanding, hence he has an added responsibility in the choice of words and construction of sentences.

The speech of most of us is filled with too many slang expressions, split infinitives, jumbled constructions and general disregard for our teachings in English to serve as a model for our writings. It isn't that we don't know better; we are just lazy, and depend on tone and inflection of voice, gestures, and facial expressions to convey our ideas, instead of well-chosen words. A study of semantics might well be included on a par with composition in formal English courses.

I cannot point to a career as a successful author to give authority to my comments, but feel that Mr. Mathis and I have a common goal in producing more effective technical reports. I am in total accord with the other guideposts he suggests.

H. O. Ervin  
Portland, Ore., Nov. 29, 1952.

# PLASTICS EQUIPMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER

The Atlas Mineral Products Co., Mertztown, Pa.

**PHENOLIC CEMENT:** An infusible plastic material based on a mixture of a liquid phenolic resin and a finely divided inert filler, such as carbon, silica or acid-washed asbestos. The powder and liquid are usually supplied in separate containers for on-the-job mixing.

**APPLICATION AND REMARKS:** A phenolic cement is prepared at the time of use by intimately mixing the phenolic liquid resin with the inert filler. The latter contains an acid which catalyzes the subsequent polymerization at ordinary temperatures. The resulting mortar is used for joining acid-proof brick and tile to protect chemical vessels, stacks and floors and also for the molding of process equipment, such as tanks, ducts,

fittings and pipes. Carbon-filled phenolic cements have excellent resistance to all non-oxidizing acids, salts and most organic solvents. Silica and asbestos-filled compositions are denser and are attacked by hydrofluoric acid and its salts.

**CHEMICAL COMPOSITION:** A typical liquid phenol-formaldehyde resin has a specific gravity of 1.1, a viscosity at 77° F. of 100 cp. and a solids content of 70%. A typical powder contains inert filler and a small amount of a specific acid catalyst such as paratoluene sulfonic acid or paratoluene sulfonyl chloride.

## MECHANICAL AND PHYSICAL PROPERTIES OF A TYPICAL CARBON-FILLED PHENOLIC CEMENT:

Tensile Strength, lb./sq.in. @ 75° F.	1.000
Elongation, %	< 1
Impact Notch, Izod, ft.lb./in.	0.2
Flexural Strength, lb./sq.in. @ 75° F.	4,000
Compressive Strength, lb./sq.in. @ 75° F.	10,000
Modulus of Rupture, lb./sq.in.	1,000
Specific Gravity	1.4
Thermal Expansion (in./in. × F. × 10 <sup>-6</sup> ) (32-212° F.)	6
Thermal Conductivity, B.t.u./(sec.) (sq.ft.) (° F./in. × 10 <sup>-4</sup> ) (32-212° F.)	1
Resistivity, ohm-cm.	15

**TEMPERATURE LIMITATIONS:** Phenolic cements are suitable for continuous service at temperatures up to 360° F.

## CORROSION RESISTANCE

### TYPICAL CARBON-FILLED PHENOLIC CEMENT

C	H	C	H	C	H
ACIDS					
Acetic, 10%	E	Ammonium Chloride, nitrate, sulfate	E	Refinery Crudes	E
Acetic, glacial	E	Copper Chloride, nitrate, sulfate	E	Trichloromethylene	E
Benzene sulfonic	E	Ferric Chloride, nitrate, sulfate	E	PAPER MILL APPLICATIONS	
Benzoic	E	Nickel Chloride, nitrate, sulfate	E	Kraft liquor	N
Boric	E	Stannic Chloride	E	Black liquor	N
Butyric	E	Zinc Chloride, nitrate, sulfate	E	Green liquor	N
Chloroacetic	E	ALKALINE SALTS		White liquor	N
Chromic, 5%	E	Barium sulfide	P	Sulfite liquor	N
Citric	E	Sodium bicarbonate	E	Chlorite bleach	E
Fatty acids	E	Sodium carbonate, 50%	E	Alum	E
Fluorosilicic	E	Sodium sulfide, 10%	E		
Formic	E	Tri sodium phosphate, 25%	E	PHOTOGRAPHIC INDUSTRY	
Hydrobromic	E	ALKALINE SALTS		Developers	E
Hydrochloric	E	Barium sulfide	P	General use	E
Hydrocyanic	E	Sodium bicarbonate	E	Silver nitrate	E
Hydrofluoric	E	Sodium carbonate, 50%	E		
Hypochlorous, 10%	E	Sodium sulfide, 10%	E	FERTILIZER INDUSTRY	
Lactic	E	Tri sodium phosphate, 25%	E	General use	E
Maleic	E				
Nitric, 5%	E	NEUTRAL SALTS		STEEL INDUSTRY	
Nitric, 10%	E	Calcium chloride, sulfate	E	Sulfuric acid pickling	E
Oleic	E	Magnesium chloride, sulfate	E	Hydrochloric acid pickling	E
Oxalic	E	Potassium chloride, sulfate	E	H <sub>2</sub> SO <sub>4</sub> -HNO <sub>3</sub> acid pickling	E
Perchloric	E	Sodium chloride, sulfate	E		
Phosphoric	E	GASES		TEXTILE INDUSTRY	
Picric	E	Chlorine, dry	F	General use	E
Stearic	E	Chlorine, wet	N		
Sulfuric, 50%	E	Sulfur dioxide, dry	E	FOOD INDUSTRY	
Sulfuric, 70%	E	Sulfur dioxide, wet	E	General use	E
Sulfuric, 93%	E			Breweries	E
Oleum	E	ORGANIC MATERIALS		Dairies	E
Mixed Acids, 57% HNO <sub>3</sub> , 28% H <sub>2</sub> SO <sub>4</sub>	N	Acetone	E		
		Alcohol, methyl, ethyl	E	MISCELLANEOUS INDUSTRIES	
ALKALIES	P	Aniline	E	Plating	E
Ammonium Hydroxide	N	Benzene	E	Petroleum	E
Calcium Hydroxide	P	Carbon tetrachloride	E	Tanning	E
Potassium Hydroxide	N	Chloroform	E	Oil and Soap	E
Sodium Hydroxide	N	Ethyl Acetate	E	Water and Sewer	E
ACID SALTS	E	Ethylen Chloride	E		
Alum or Aluminum Sulfate	E	Formaldehyde, 37%	E		
		Phenol, 5%	E		

#### RATINGS:

- E—No attack.
- G—Appreciably no attack.
- F—Some attack but usable in some instances.
- P—Attacked—not recommended.

- N—Badly attacked.
- C—Cold—70° F.
- H—Hot—250° F. or boiling point of test solution.

No. 17

# RESORT MEETING FOR A.I.Ch.E. IN MARCH

The technical meeting to be held at the Buena Vista Hotel, Biloxi, Miss., on March 8 to 11 will be devoted in large part to a symposium on mineral engineering techniques. Preliminary details of the program appeared in the December issue on page 34. The symposium will extend over the first two days of the meeting and will consist of papers on various aspects of the subject, followed by round-table discussions. Other symposia will consider hydrometallurgical processes and fluid mechanics, and there will be a nontechnical session on methods of streamlining paper shuffling. The complete program will appear in the February issue.

The resort meeting, held at the end of the winter, offers a pleasant change from industrial and commercial centers and is usually less expensive than other types of meetings. Aside from the technical sessions, few activities will be planned, but there are ample opportunities for recreation. By extending their time in Biloxi, members may enjoy a warm-weather vacation to suit a variety of interests.

## Mississippi Gulf Coast

Informality is the keynote of the Mississippi Gulf Coast, America's Riviera. Sports are the main attraction of the twenty-six-mile-long waterfront, where swimming—even in March for hardy Northerners—, fishing from the wharves or from deep-sea boats, and sunbathing are available. Away from the coast, the streams offer bass, bream, and crappie for fresh-water fishermen, and several tennis courts, and three golf courses (green fee, \$1.65; caddy fee, \$1.50) are within five miles of the hotel.

For fishermen, a number of half- and full-day (or longer) fishing trips, averaging \$50 a day, including tackle, bait, and ice, for 5 to 10 persons are available, as are small boats for use on the bays and streams. Those who prefer bathing will find the hotel's private beach pleasant and convenient.

Biloxi also has attractions for the historical-minded visitor. It is one of the oldest settlements in America, having been founded by French explorers in 1699. Once the capital of the Louisiana Purchase Territory, the city is historically interesting for its French and Spanish colonial associations as well as for



A view of the Yacht Club at Biloxi, not far from the Buena Vista Hotel. The Lipton Cup Fish-class Races are held here annually.

its connections with United States history, specifically with the War of 1812 and the Confederacy.

Modern Biloxi still preserves many of its antebellum homes, including Beauvoir, the last home of Jefferson Davis, where he wrote "The Rise and Fall of the Confederate Government"; the Wood home, a plantation cottage typical of the region, with a raised main floor reached by a curved double staircase; Spanish House, built about 1790 and the sole relic of the period of Spanish rule in Biloxi; and French House, built before 1800. Also of interest are the lighthouse, dating from 1848 and tended for 62 years by a mother and daughter; Old Biloxi Cemetery, where are buried many of the first settlers of the region; ring-in-the-oak, an ancient live oak perpetuating a romantic Indian legend; and Ship Island, 12 miles south of Biloxi and the base for the British fleet that tried to take New Orleans during the War of 1812.

Attractive drives and walks in the vicinity are Memorial Bridge, over the historic Bay of Biloxi; a 30-mile scenic highway along the Gulf, acclaimed as one of the most beautiful drives in America; and the paths on Deer Island, loveliest of the coastal islands and renowned for its legends of Indians and buried pirate treasure.

After a long winter, a few days on the Gulf Coast, which is reputedly the healthiest locality in the South, offer an enjoyable change. Good regional cooking and some of the world's best drinking water from deep artesian wells are further attractions of this pleasure spot, whose sheltered location assures a pleasant March climate of warm sunny days and cool nights, the average temperature

being 67.2° F. Top coats are advisable, although they are often unnecessary during the day. Sports clothes are usually worn throughout one's visit.

## Travel and Accommodations

Those arriving by train from the West and North will find train or bus connections for Biloxi at New Orleans; from the East the Southern and the Louisville and Nashville railroads go directly to Biloxi. National Airlines and Southern Airways service Biloxi from the Gulfport, Miss., airport, 10 miles from the hotel.

The Buena Vista Hotel offers the American plan, often desirable at resorts, at \$12.50 a person a day and the European plan from \$3.25 to \$7.50 daily per person. Cottages with complete hotel service are also available at the Whitehouse, a Colonial-style hotel within walking distance of the Buena Vista.



Norman A. Spector (left), process engineer, Vitro Corp., New York, is Technical Program Chairman of the Biloxi meeting; D. W. Oakley (right), assistant plant manager, Metal and Thermit Corp., Carteret, N. J., is co-chairman of the symposium on mineral engineering techniques.

# CLEVELAND MEETING



A group attending the "Human Relations" luncheon program. Clockwise around table: E. W. Kane, Standard Oil Co. (Ind.); R. L. Hatch, General Electric Co.; R. E. Norris, Vulcan Engineering Div.; E. W. White, Cities Service Research and Development Co.; A. W. Hunt, Carter Oil Co.; and John W. Shier, Acheson Colloids Co.



Top: left (standing) L. S. Coonley chaired a group of speakers who presented general technical papers. With him is Robert D. Ingebo. Seated: A. E. Karr, R. L. Jacks, and W. B. Argo.

Bottom: Another group who presented general technical papers. They are (standing): P. L. Young, and C. O. Miller. The latter was general chairman of the Cleveland Annual Meeting. Seated: H. E. Benson, H. A. Sommers, and H. J. Kruse.



Except for the New York Annual Meeting of 1948, registration was the highest in history.



Carl C. Monrad, Carnegie Institute of Technology; A. H. White (standing), University of Michigan; and Francis C. Frary, past president of A.I.Ch.E.



Cuthbert Daniel (left) presided over a symposium on statistical methods. With him are W. J. Youden, National Bureau of Standards; Hugh Smallwood, U. S. Rubber Co.; and K. A. Brownlee, University of Chicago.



The meeting opened with a panel discussion on "Local Sections." At the microphone is C. E. Ford, chairman of this group. Also shown are J. L. Olsen, Sun Oil Co.; and W. T. Nichols, who was elected President of A.I.Ch.E. for 1953.

# TYGON

## Versus

PURE alcohols usually are not corrosive. However, under certain conditions, in aqueous solutions, or in combination with other chemicals, they can and do give trouble. Alcoholic solutions of acids and bases, tinctures, and the use of denaturants offer a complicated picture of corrosive attack. Additionally, the organic nature of alcohols warrants special consideration in their use with the TYGON family of plastic compounds.

The TYGON family is a series of vinyl based compounds—selected polyvinyl resins carefully modified with other materials to give the maximum in general chemical resistance and physical properties. There are a number of standard and special compounds available in the form of calendered or press-polished sheeting, molded goods, extrusions, paint and plastisols. Some are non-toxic, others are not. Some are glass-clear, some are glossy black, still others are available in practically any color. A wide range of physical and mechanical properties are exhibited. Many different types of applications are possible.

In any of its forms, TYGON displays excellent resistance to both simple and polybasic alcohols in any concentration. Service temperatures are limited only by the boiling points of the alcohols involved. Where alcohols are used in combination with other chemicals, preliminary tests or the counsel of U. S. Stoneware engineers is advised. In these cases, the particular additives used govern the suitability of TYGON and its service limits.

Because of the organic nature of the two materials, a certain amount of trace extraction takes place whenever TYGON is used in full contact with alcohols. The total extraction is very low—almost negligible. It usually results in a slight hardening and stiffening, a slight loss of weight and a slight color change. Generally speaking, these

changes are barely noticeable and do not affect the protectability of the TYGON.

Another factor to remember in the use of TYGON with alcohols involves its use with tinctures. Occasionally, the color of the material in solution is imparted to the TYGON. Once again, however, the protectability and functioning of the TYGON is unaffected excepting where solution visibility is important.

TYGON as calendered or press-polished sheeting is used primarily to line and cover all types of process equipment. It also is die-cut into gaskets, seals, and separators for a wide variety of uses.

In molded form, TYGON has even wider application—a range of uses limited only by the size and shape that can be imparted to a thermoplastic material by mold and press.

In the form of extrusions, TYGON's major use is as flexible tubing and piping. In both plant and laboratory, strong, light, glass-clear, and fully flexible TYGON Tubing has done much to simplify the problem of transmitting corrosive liquids, gases, or semi-solids. Extruded solid cord and channel also find use as gasketing, expansion jointing, and packing.

As a paint, TYGON is used to protect equipment, structural steel, walls, and ceilings against corrosive fumes and spillage. As a plastisol, TYGON is used as a heavier duty coating and in the casting or "slush" molding of flexible parts and fittings.

For most applications, TYGON in its various forms is a very practical material for use with alcohols and mixtures of alcohols with other chemicals. Occasionally, limits may be imposed by the added chemicals or by the need for absolute purity. However, these are isolated cases. TYGON can be safely regarded as an economical and effective material of construction, medium of transmission and protective coating for use with alcohols.

*In addition to TYGON in its various forms, we also manufacture a number of other materials capable of handling alcohols and their mixtures with other chemicals in any concentration and under all types of operating conditions. These products include chemical stoneware and porcelain, acid proof brick and cements, homogenous lead linings, and other organic linings and coatings.*

*Why don't you submit your corrosion problem today? There's no obligation and we'll be pleased to be of assistance. So write, now!*



420

**THE UNITED STATES STONEWARE CO., Akron 9, Ohio**

ENGINEERS, MANUFACTURERS, ERECTORS OF CORROSION-RESISTANT EQUIPMENT SINCE 1865



J. M. Lenoir, University of Arkansas, presented a paper on thermal conductivities of gases at high pressure.



W. A. Junk, Standard Oil Co. (Ind.).



Loren P. Scoville, Jefferson Chemical Co., Inc., new chairman of the Program Committee.



W. I. Burt, Goodrich Chemical Co., and 1952 A.I.Ch.E. President, speaks at Annual Awards banquet.



George F. Jenkins, Carbide and Carbon Chemicals Corp., and chairman of the Public Relations Committee.



F. H. Kirkpatrick speaks at "Human Relations" luncheon. Seated: R. L. Denmerle, who presided; and T. H. Chilton, Du Pont Co., past president of A.I.Ch.E.

# CLEVELAND

## ANNUAL MEETING NEARS RECORD HIGH

**C**leveland as a chemical center proved its vitality last month when the American Institute of Chemical Engineers met Dec. 7-10, for its forty-fifth annual meeting. The centrality of the location was shown when attendance mounted to 1925, and at the end of the four-day session, Cleveland was on record as having held the second largest annual meeting in the history of the Institute.

The four days were replete with symposia, panels, committee meetings, technical sessions and an annual business meeting where one of the important developments was the announcement by C. R. DeLong, of a wish to retire as the Institute's treasurer. After reporting briefly on the Institute's financial status (at a higher level than ever before), Mr. DeLong announced that he had a far more important matter to present to the membership. He began by stating that he had no desire to continue for another year as treasurer of the Institute, and reminded the members that this had been announced on the nominating ballots. In spite of that, he was nominated and proved to be the only candidate on the ballots. Mr. DeLong continued, "After 16 years one man has had enough of one job. I have told the new council for 1953, that if they will take the responsibility of finding a man who they feel is qualified for the office of treasurer, and they have undertaken to do so, I shall be glad to resign and have him take office. I will be glad to spend any amount of time necessary to help him in the task of treasurer," Mr. DeLong continued. "In conclusion, I wish to say to the members that it is not only a distinct honor, but also a great pleasure to have been your treasurer for the past sixteen years."

The desire of Mr. DeLong to retire as treasurer was indicated to the members when the nominating ballots were sent out in September. At that time, nominated for treasurer along with DeLong, were R. P. Soule, C. G. Kirkbride who was also nominated for Vice-President, L. P. Scoville also nominated for Director. All three, however, declined to run for treasurer and Mr. DeLong agreed in order to fill the blank on the ballot.

Other events of the business meeting were the introduction of new officers

(reported last month in Chemical Engineering Progress), and reports from various committees. These will all be condensed in the Secretary's page in future issues of "C.E.P."

One of the major events of the meeting was the Awards banquet Tuesday night. As also reported last month in Chemical Engineering Progress, awards were made to the following: Professional Progress Award to Professor R. H. Wilhelm, department of chemical engineering, Princeton University; William H. Walker Award to Prof. J. Henry Rushton, department of chemical engineering, Illinois Institute of Technology; Junior Award to Thomas Baron, Shell Development Co., and Lloyd G. Alexander, Oak Ridge National Laboratory; A. McLaren White Award to Harold F. Hublein now with Du Pont Co., Inc., Wilmington, Del. Second and third prizes in the student contest group went to Rodney A. Nelson and David G. Stephan.

The Awards banquet featured an address by John B. Collyer, president B. F. Goodrich Co., in which he called on private enterprise to enter the atomic energy field.

"Nationalization of our power industry and other closely allied industries is inevitable unless the American people insist that non-military developments in the field of atomic energy be privately operated and privately financed," he said.

Collyer warned that "the utility of the atom must not be locked in the straight-jacket of bureaucracy." He pointed out that today's decisions on whether atomic energy will remain a government monopoly are bound to have tremendous impact on the field of private investment.

"Our long-range national security requires continued progress in research and development which can come only from dynamic and competitive privately-owned industry," he said. Collyer pointed out that he has consistently advocated the disposal to private industry of the government-owned man-made rubber plants. "By this step," he said, "we can reverse the trend towards socialism in rubber."

"Today, seven years after the end of the war, our government still owns the principal rubber-producing facilities in

(Continued on page 35)  
(More Pictures on page 36)

# ON-STREAM!

## On-time --- On-budget



This \$10,000,000 refinery modernization project for Standard Oil of Texas at El Paso was completed five days ahead of schedule—despite the steel strike. It was completed within the budget—despite cost increases in material and labor.

Catalytic's undivided responsibility covered engineering, procurement and construction—and accomplished the field work in ten months from date of installation of construction facilities.

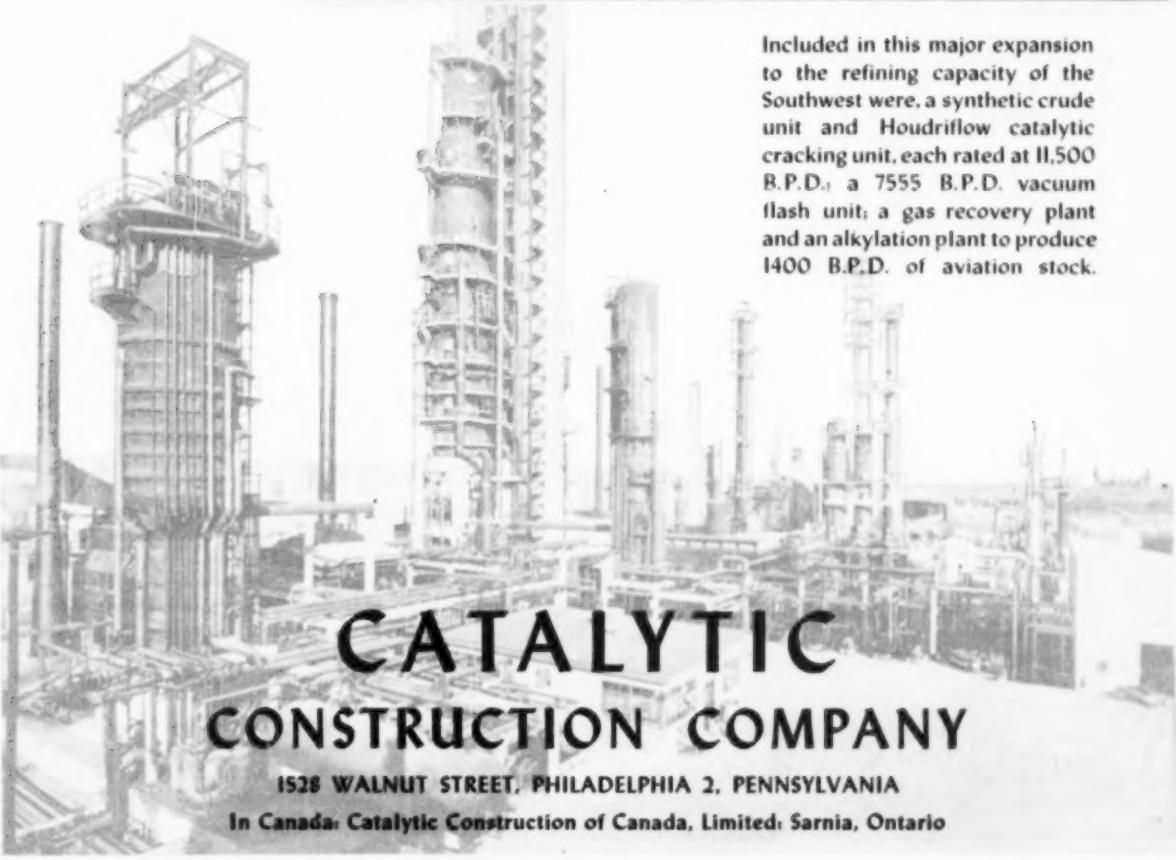
### CATALYTIC ON-TIME . . . ON-BUDGET SERVICES

for the chemical, petrochemical and oil refining industries

Project Analysis      Engineering      Economic Studies

Procurement      Process Design      Construction      Plant Operation

Included in this major expansion to the refining capacity of the Southwest were, a synthetic crude unit and Houdriflow catalytic cracking unit, each rated at 11,500 B.P.D.; a 7555 B.P.D. vacuum flash unit; a gas recovery plant and an alkylation plant to produce 1400 B.P.D. of aviation stock.



## CATALYTIC CONSTRUCTION COMPANY

1528 WALNUT STREET, PHILADELPHIA 2, PENNSYLVANIA

In Canada: Catalytic Construction of Canada, Limited: Sarnia, Ontario



Above: the first tank car being loaded for shipment from Carbide and Carbon Chemicals Company's coal-hydrogenation pilot plant. This product, a mixture of low-boiling phenols, will be used in the manufacture of plastics. It left the Institute, W. Va., plant on November 15. Coal-hydrogenation chemicals-separation units are in the right background, with the finished chemical storage tanks on the left.

## ATTAPULGUS TO MINERALS SEPARATION

Sale of the fullers earth business of the former Attapulgus Clay Co. to Minerals Separation North American Corp., the combined business operating under the new name of Attapulgus Minerals & Chemicals Corp. was recently announced.

Attapulgus Clay Co. was a factor in the mining and manufacture of various fullers earth products used as adsorbents and refining mediums, and diluents for insecticide dusts. Minerals Separation North American Corp. is engaged in the development of flotation processes for the beneficiation of industrial minerals.

Officers of the new corporation include:

David E. Lilienthal, chairman of the board, and former chairman of the Atomic Energy Commission.

L. R. Streander, president.

R. H. Hubbell, Jr., vice-president in charge of sales.

Dr. E. W. Greene, vice-president in charge of Minerals Separation division.

W. E. Sawyer, Jr., secretary and treasurer.

In addition to officers of the company, two new directors were added to the board of the newly named and expanded company, Frank A. Howard, formerly vice-president of Standard Oil Company (New Jersey); and Ernest K. Gladding, until recently development chief for Du Pont Co.

## COLOR AND SOUND FILM ON STEAM TRAPPING

"Please Pass the Condensate" is a new 20-min. color and sound motion picture prepared by the Yarnall-Waring Co., Philadelphia 18, Pa., on up-to-date steam trapping for more production.

It portrays the operation, selection, application and maintenance of steam traps—all with the ultimate aim of getting more production from steam-heated equipment through reduced heat-up time and hotter operating temperature, as well as shortened downtime for repairs and cleaning.

Information on obtaining prints for showing to engineering and plant groups may be secured by writing the Yarnall-Waring Co.

## PETROCHEMICALS FOR GULF AND GOODRICH

The establishment of Goodrich-Gulf Chemicals, Inc., a Delaware Corporation, was announced recently by Gulf Oil Corp. and B. F. Goodrich Co. Organized to explore projects in the petrochemical field in which the parent organizations have complementary interests, the new company will have its head office in Pittsburgh, Pa., and its plant in Orange, Tex. Stock will be owned equally by Gulf and Goodrich.

Among the directors of the new company are L. O. Crockett of Gulf Oil and Frank K. Schoenfeld of B. F. Goodrich.

## ENGINEERING LITERATURE SURVEYED

The present state of engineering literature is the theme of the recently published proceedings of the Engineering School Libraries Committee of the American Society for Engineering Education. The decision to publish the papers was made because of the interest in them shown at the annual meeting of the society held at Dartmouth College, Hanover, N. H., June, 1952. Consisting of a panel discussion and commentaries, the papers consider quality, dissemination of modern engineering literature, etc.

Contributors are James K. Finch, dean emeritus, School of Engineering, Columbia University; Samuel A. Miles, technical literature division, Hagstrom Co.; Edward P. Hamilton, president, John Wiley & Sons; Vernon D. Tate, director of libraries, Massachusetts Institute of Technology; Curtis G. Benjamin, McGraw-Hill Book Co.; Fred P. Peters, manager, book division, Reinhold Publishing Corp.; Rogers B. Finch, professor of textile technology, Massachusetts Institute of Technology; and F. J. Van Antwerpen, editor, "C.E.P."

Appended to the discussions are a tabulated survey of existing types of library training in engineering colleges and a summary of findings on the use of engineering libraries.

Copies may be obtained from George S. Bonn, chairman, Engineering School Libraries Committee, A.S.E.E., the Rice Institute, Houston, Tex.

## REGIONAL STUDENT CONTEST AWARDS

Winners of a student-paper contest sponsored by several student chapters in western states were awarded cash prizes and a year's subscription to "C.E.P." at the regional meeting of the area held at the University of Arkansas, Fayetteville, on Dec. 13, 1952. Gerald D. Orloff of Oklahoma A. & M. College, Stillwater, and Melvin C. Reed of the University of Tulsa, Tulsa, Okla., received first and second prizes respectively, and honorable mention went to Wayne House, Univ. of Missouri.

Judges of the contest were Dr. William K. Noyce, University of Arkansas, chairman; Dr. Louis H. Bartlett, Oklahoma A. & M. College; and Dr. J. O. Maloney, Kansas State University. Dr. M. E. Barker, counsellor of the Arkansas chapter, made the presentations.

Among the schools participating in the contest were the Universities of Arkansas, Kansas, Missouri, Nebraska, Oklahoma, and Tulsa; Kansas State College; the Missouri School of Mines; and Oklahoma A. & M. College.

(More News on page 43)

# **Accidental Thermal Shock?**

**...THERE'S NOTHING  
FRAGILE ABOUT**

# **Lapp TUFCLAD**



**SOLID** Chemical Porcelain **ARMORED** with Fiberglass-Reinforced Plastic

**Now** you can gain the advantage of solid chemical porcelain purity and chemical resistance in a system which offers extra protection to personnel, equipment and product. Lapp TUFCLAD armor—multiple layers of Fiberglass fabric impregnated and bonded to the porcelain body with an Epoxide resin of high strength and chemical resistance—cushions accidental blows, insulates against thermal shock. Besides, it is itself tough and strong—will hold operating pressures against gross leakage, even if porcelain is cracked or broken. WRITE for description and specifications on Lapp TUFCLAD porcelain valves, plug cocks, safety valves, flush valves, pipe, fittings and special shapes.

Lapp Insulator Co., Inc., Process Equipment Division, 519 Maple St., Le Roy, N. Y.



## Widest choice . . . for engineered instrumentation

Each of the thousands of industrial processes presents its own peculiar problems of measurement and control. Naturally, no single instrument can solve all of these varied problems. Serious compromises would have to be made in performance, convenience, and cost.

The many Honeywell primary elements, instruments, control systems, and final control elements constitute a uniquely complete family, covering practically the whole spectrum of industrial measurement and control. You can be sure that the combination selected for your job is recommended without bias, and with full consideration for every need of the application.

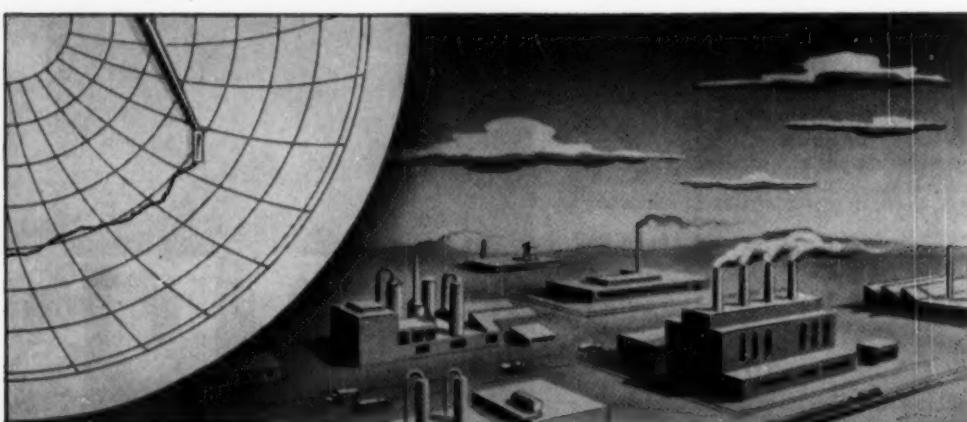
Included are *Electronik* instruments for indicating, recording and controlling a host of variables, in circular and strip chart models; *Tel-O-Set* miniature indicators, recorders and controllers; *Pyr-O-Vane* millivoltmeter controllers; square root and linear flow meters; thermometers; pressure gauges. Electric and pneumatic control systems range from the simplest to the most complex, including fully automatic program control. Primary elements include thermocouples, thermometer bulbs, *Radiamatic* elements, pH assemblies, conductivity cells, flow meter bodies and many others. For final control elements, there is a

full range of motorized and diaphragm operated valves. Supplementing these are more than 7000 different non-indicating devices for controlling temperature, pressure, vacuum and other conditions.

### "Building block" approach

These are the building blocks of measurement and control. To combine them into systems custom-fitted to your process, Honeywell offers the know-how gained through years of experience in all branches of industry. Whether your process calls for a single instrument or a complete central control panel, you can be sure of getting the peak in performance and value . . . and the advantages of a single responsibility for the entire installation . . . when you specify *engineered instrumentation by Honeywell*.

# Engineered to Lever



**COMPLETE COVERAGE** of industrial requirements for instrumentation is at your command in the Honeywell line. Whatever you need to measure or control . . . to any accuracy . . . with any of a variety of special features . . . you'll find Honeywell instruments offer the most efficient solution.

THE NEW Los Angeles plant of Lever Brothers Company utilizes the most modern methods for processing raw oils and fats into soaps, detergents and shortening. Prominent among these advanced techniques is Brown engineered instrumentation for every critical process.

In the manufacture of Spry vegetable shortening, for example, Brown instruments help to control refining, bleaching, hydrogenation and deodorizing at top output and efficiency. Companion instruments also regulate the saponification, spray drying, extrusion and other processes vital to the manufacture of toilet soaps, soap powders and detergents. Throughout the plant, Honeywell controls keep critical variables in line with the precision essential to efficient, high-volume production.

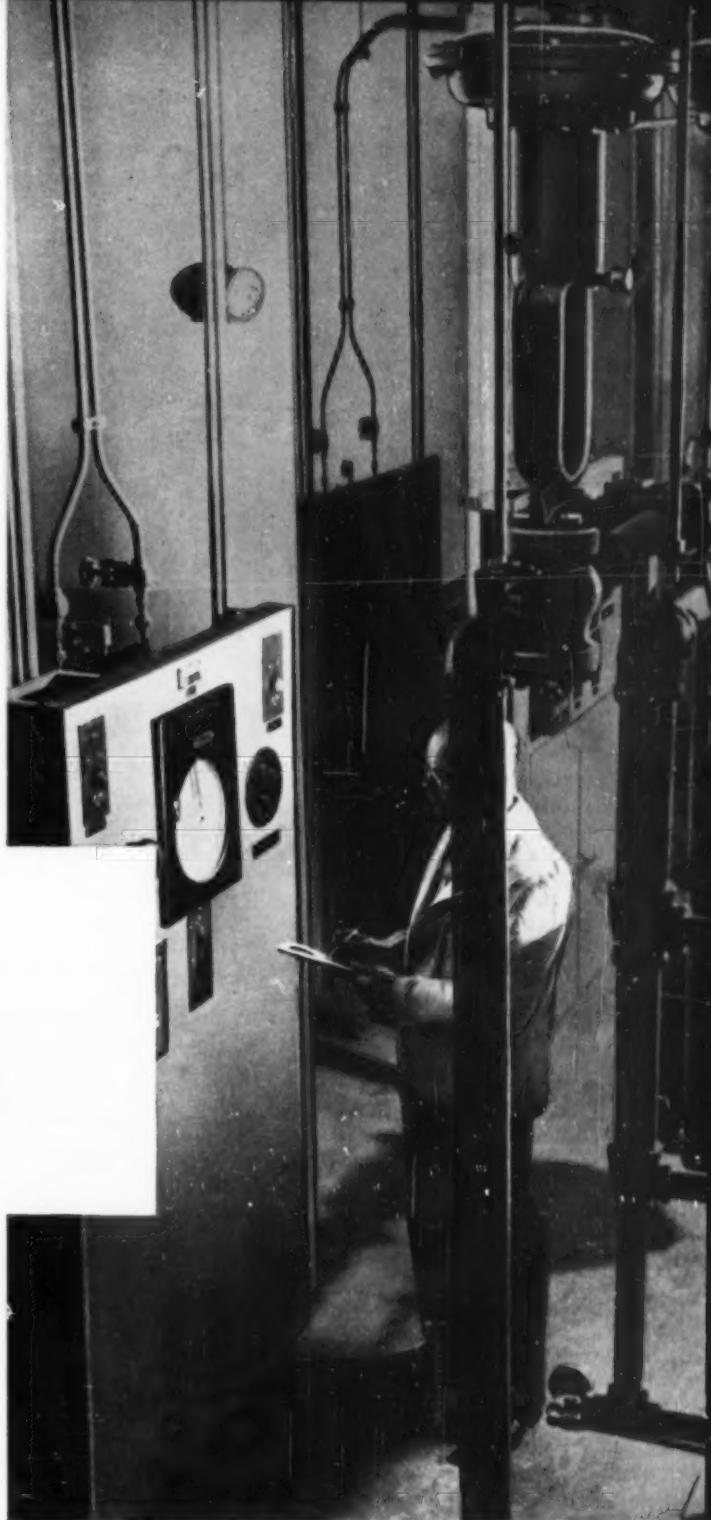
Whatever your process may be, you can be sure of getting from Brown the right instrumentation . . . properly applied. First, because the Brown line covers *every* major control requirement of the chemical industry. And second, because these instruments are custom fitted to your application by engineers who have thorough experience in process control.

## control vital Brothers plant

Our local engineering representative is well qualified to recommend instrumentation for your processes . . . and he is as near as your phone.

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GAS FLOW to Surf spray tower heaters is recorded by Brown Flow Meter . . . one of many in this plant. At top are Honeywell diaphragm control valves.

MINNEAPOLIS  
**Honeywell**  
BROWN INSTRUMENTS

First in Controls



# MARGINAL NOTES

News of Books of Interest to Chemical Engineers

## What's In a Handbook?

**Handbook of Engineering Fundamentals,** 2nd Edition. O. W. Eshbach. John Wiley & Sons, Inc., New York. (1952) 1314 pp., \$10.00.

Reviewed by C. K. Stoddard, Titanium Metals Corporation of America, Henderson, Nev.

THIS handbook is described by its author as an attempt "to bring together the most important basic facts and principles upon which our technological and engineering advancement depends." How well this has been done is difficult to evaluate since there appears to be considerable difference of opinion as to what should be in a handbook. This was brought out by putting this question to a number of engineering associates. Answers ranged from a mere compilation of tables and numerical data to a rather comprehensive combination of principles, methods and data that represent the highest authority of knowledge in a particular field. One engineer felt that a handbook would be the starting place in seeking information about a given engineering subject, while another felt that a complete answer should be found. To a large extent, this handbook appears to provide the starting place for information concerning many of its topics. The mathematical tables and data are the more or less standard material of all handbooks.

The information is presented under the following headings: mathematical and physical tables, mathematics, physical units and standards, mechanics of rigid bodies, mechanics of deformable bodies, aerodynamics, engineering thermodynamics, electricity and magnetism, radiation light and acoustics, chemistry, metallic materials, non-metallic materials, and engineering law. These topics are variously developed by many contributors, all being experts or specialists in their particular fields. The chemical engineer would probably regard the book as a source of information in fields other than chemical engineering. It appears to this reviewer that the textual material, in some cases, could have been better presented to the engineer seeking a start in fields other than his own by a more interpretive presentation, thus giving him a knowledge of what the field embraces, the techniques and approaches used for the solution of its

problems, and how the information is useful. At random, this could have been done for hydraulic models, and the testing of materials by giving ranges of numerical data for various materials. In many places excellent interpretive approaches are given such as for the design of supersonic wind tunnels and much of the aerodynamic material. Those chapters that concern particular fields of engineering, such as aerodynamics, radiation light and acoustics, etc., have excellent lists of references to enable the reader to seek additional information elsewhere. The mathematical tables are well presented and especially the tables of conversion factors which are set up so as to make the improper use of an unfamiliar conversion factor quite improbable. The values and bases of many obscure measures and standards are given. There is considerable general information in this handbook which should make it a useful reference on the engineer's bookshelf.

## Books Received

**Biochemical Preparations. Vol. 2.** Eric G. Ball, Editor in Chief. John Wiley & Sons, Inc., New York, (1952). 109 pp. \$3.00.

**Maleic Anhydride Derivatives — Reactions of the Double Bond.** L. H. Flett and W. H. Gardner. John Wiley & Sons, Inc., New York (1952). 269 pp. \$6.50.

**Impfections in Nearly Perfect Crystals.** Eds. W. Shockley, J. H. Hollomon, R. Maurer, and F. Seitz. John Wiley & Sons, Inc., New York (1952). 475 pp., \$7.50.

**An Introduction to the Chemistry of the Hydrides.** Dallas T. Hurd. John Wiley & Sons, Inc., New York (1952). 220 pp., \$5.50.

**Selected Values of Chemical Thermodynamic Properties.** Frederick D. Rossini, Donald D. Wagman, William H. Evans, Samuel Levine, and Irving Jaffe. National Bureau of Standards, Washington, D. C. (1952). 1268 pp., \$7.25.

**Technical Cooperation with Underdeveloped Countries.** Philip C. Newman, John E. Ullmann, Robert S. Aries. Chemonomics, Inc., New York (1952). 96 pp., \$5.00.

**Investment Castings for Engineers.** Rawson L. Wood and David Lee Von Ludwig. Reinhold Publishing Corp., New York (1952). 477 pp. \$10.00.

## Current Thoughts on Radiation Effects

**Symposium on Radiobiology, The Basic Aspects of Radiation Effects on Living Systems.** Editor J. J. Nickson, M.D. John Wiley & Sons, Inc., New York. (1952) xii + 465 pp., \$7.50.

Reviewed by J. Kohl, Chief Engr., Western Division, Tracerlab, Inc., Berkeley, Calif.

THIS report on papers and discussions presented at the Oberlin Symposium on Radiobiology in June, 1950, should be of considerable value to scientists concerned with the biological aspects of radiation effects. It presents the current thinking of leaders in radiobiology and summarizes progress and changes in philosophy that have taken place since the publication of D. E. Lea's book, "Actions of Radiation on Living Cells," (1947). Since this book assumes a basic knowledge of radiation phenomena and language and also requires a working knowledge of medical and bacteriological terms, it is further limited to this specialized group.

Little actual data on chemical reactions produced or accelerated by radiation, and no discussion on Health Physics problems of interest to engineers are contained in the symposium. Of the twenty-three essays which comprise the book, two are of possible interest to chemical engineers: *General Statements About Chemical Reactions Induced by Ionizing Radiation* by Robert Livingston and *Chemical Reactions in the Gas Phase Connected with Ionization* by Merrill Wallenstein, Austin L. Wahrhaftig, Henry Rosenstock, and Henry Eyring.

As a reference text the symposium's value is impaired by the absence of an index and by the lack of cross-references between material presented in the discussions and in the chapters. When a book is written by twenty-six authors rather than one a certain lack of consistency is to be expected. In this book one chapter offers one reference, while another lists 141; some authors tabulate their references alphabetically, others in the order in which they occur.

In spite of its shortcomings, this book presents fundamental concepts concerning the relationship between biology and nuclear physics in the interesting language of discovery and early telling.

**NO JOB TOO  
LARGE...  
NO SERVICE TOO  
TOUGH...**



*BAH! THIS  
'KARBATE'  
EQUIPMENT IS NOT  
FOR ME!*

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... point to "Eveready" No. 1050 Industrial Flashlight Batteries ... the cells that deliver twice as much usable light as any battery we've ever made before. Their unique construction prevents swelling or jamming in the case ... has no metal can to leak or corrode.



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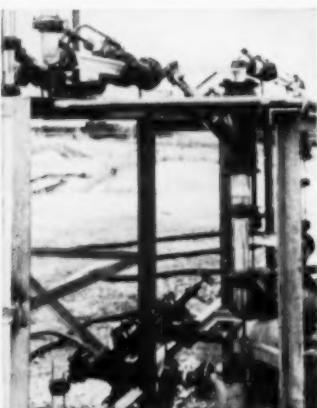
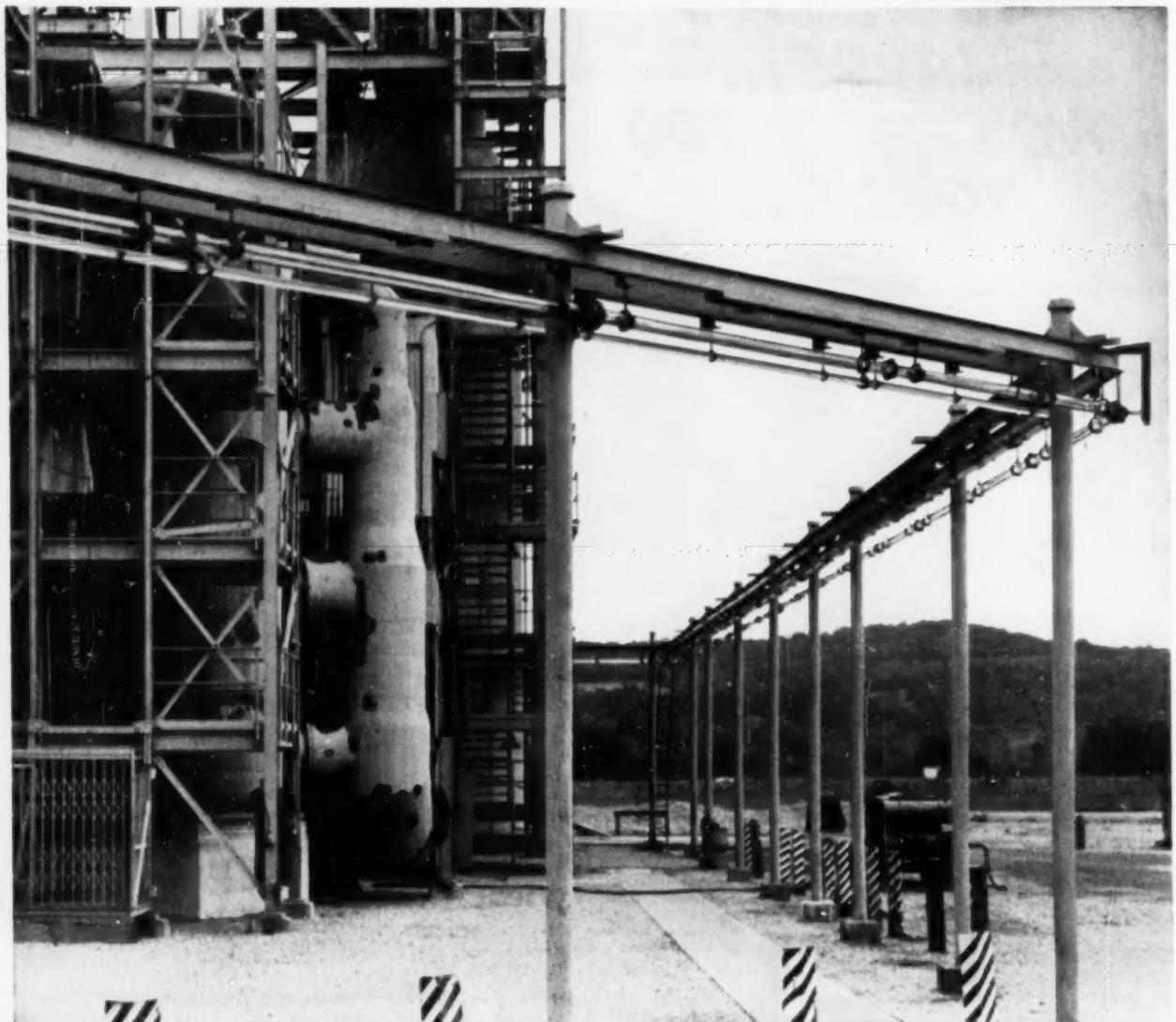
for  
**"KARBATE"**  
BRAND  
**HEAT EXCHANGERS**

**CAPACITY.** There is virtually no limit to the amount of heat-transfer surface obtainable in "Karbate" impervious graphite shell-and-tube-type heat exchangers. Large capacity requirements are readily met, either by a combination of standard Series 310A and 90A "Karbate" heat exchangers or with special units manufactured by the country's leading producers of heat exchange equipment.

**APPLICATION.** There's ample evidence that "Karbate" heat exchangers already occupy an important place in practically every type of severely corrosive service. For example, among suppliers of heat-transfer equipment for the process industries, there are 57 manufacturers and service organizations who now depend on "Karbate" impervious graphite equipment to solve their customers' toughest corrosion problems!

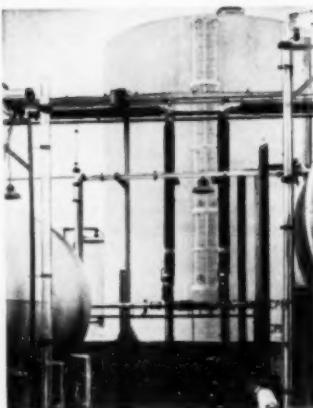
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New Standard "Karbate" Heat Exchangers

# Acid corrosion of transfer lines no problem



**Transparent and easy to clean.** Transparency is one of the plus features. It permits plant men to keep an eye on the lines—note color deformity, impurities, clogging and other defects at a glance. Trouble can't hide behind glass.

Still another, is easy cleaning. The hard, smooth surface of PYREX pipe minimizes solids adherence, eliminates grooves and depressions where material might gather.



**Resists thermal shock and weathering.** Low expansion coefficient of PYREX brand glass No. 7740 gives PYREX pipe exceptional thermal resistance. Rapid shocks of 150° F. and more leave the lines unharmed. Hot acids can be run in cold weather. Chemical stability assures resistance to sunlight and moisture.



## CORNING GLASS WORKS

**at BAKELITE'S\* Marietta plant**

# **PYREX® brand "DOUBLE - TOUGH" GLASS PIPE is in the picture**

In selecting a piping material for transferring acids at its Marietta, Ohio plant, Bakelite Company took several points into consideration. First cost was important. So was service life. This meant a piping material which would provide utmost resistance to acids day-after-day, year-after-year. Resistance to thermal shock and weathering was also important because the pipe was to be used outside in a climate known for its temperature extremes.

You can see how Bakelite solved its problems...with PYREX brand "Double-Tough" glass pipe. Not only was PYREX pipe low in first cost, extremely high in chemical and thermal resistance, but it offered several important extras, including transparency, easy cleaning, light weight and simple installation, together with exceptional mechanical strength.

\*A Division of Union Carbide and Carbon Corporation

Whether you are handling hot or cold concentrated acids (except hydrofluoric), mild alkalies or pharmaceuticals, you'll find PYREX pipe the safest and most economical material that you can use.

### **Readily available in many sizes**

It is readily available in the following sizes—1", 1½", 2", 3", 4" and 6" inside diameters. A complete line of fittings including ell's, tees, crosses, reducers, adapters, laterals, return bends and caps may be had. Glass plug valves are available in 1" and 1½" sizes. There are a wide variety of gaskets now in stock to resist virtually every chemical known. Light weight permits easy, economical installation with long lines. Your own plant help can do this job.

### **These PYREX brand glass pipe distributors stock the complete line:**

**ALBANY 5, NEW YORK**  
A. J. Eckert Company

**CHICAGO 44, ILLINOIS**  
Fred S. Hickey, Inc.

**HOUSTON 7, TEXAS**  
W. H. Curtin & Company

**ST. LOUIS 2, MISSOURI**  
Stemmerich Supply Inc.

**NEW ORLEANS, LOUISIANA**  
W. H. Curtin & Company

**ATLANTA, GEORGIA**  
Southern Scientific Company

**FRESNO 17, CALIFORNIA**  
Valley Fdy. & Mach. Works

**PITTSBURGH 19, PA.**  
Fisher Scientific Company

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Mooney Brothers Corporation

**TORONTO, ONTARIO, CAN.**  
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**BELMONT, CALIFORNIA**  
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**HATBORO, PENNSYLVANIA**  
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**MONTREAL 3, QUEBEC, CAN.**  
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**BUFFALO 13, NEW YORK**  
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**VANCOUVER, B. C.**  
Scientific Supplies

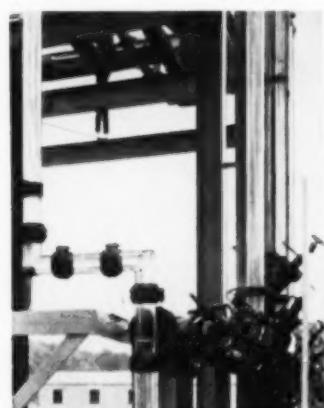
**CAMBRIDGE 39, MASS.**  
Macalaster Bicknell Company

**ROCHESTER 3, NEW YORK**  
Will Corporation

**SEATTLE 4, WASHINGTON**  
Scientific Supplies

**NEW HAVEN, CONNECTICUT**  
Macalaster Bicknell Company

**PYREX brand "DOUBLE-TOUGH" Glass Pipe for drainage lines.** A relatively new and rapidly spreading application for PYREX brand "DOUBLE-TOUGH" glass pipe is in draining corrosive wastes. Many plants have realized substantial savings because PYREX pipe virtually eliminates replacement problems. Then too, installation costs are lower because PYREX pipe does not require burial in concrete, and safety is greatly improved. Complete fittings (including sink traps) are available.



**Mechanically strong.** There's no need to worry about mechanical damage to PYREX pipe. First, it has proven over 25 years that it can take a beating. Second, ends and fittings (except U-bends) are tempered to double their strength. Third, plant men realize that it is glass and treat it with respect.

### **CORNING GLASS WORKS**

#### **Dept. EP-1, Corning, N. Y.**

Please send me the printed information checked below:

- "PYREX brand Glass Pipe in the Process Industries" (EA-1)
- "PYREX brand "Double-Tough" Glass Pipe and Fittings" (EA-3)
- "Plant Equipment Glassware for Process Industries" (EB-1)
- "Installation Manual" for PYREX brand "Double-Tough" Glass Pipe (PE-3)
- "PYREX Cascade Coolers" (PE-8)

Name \_\_\_\_\_

Title \_\_\_\_\_

Company \_\_\_\_\_

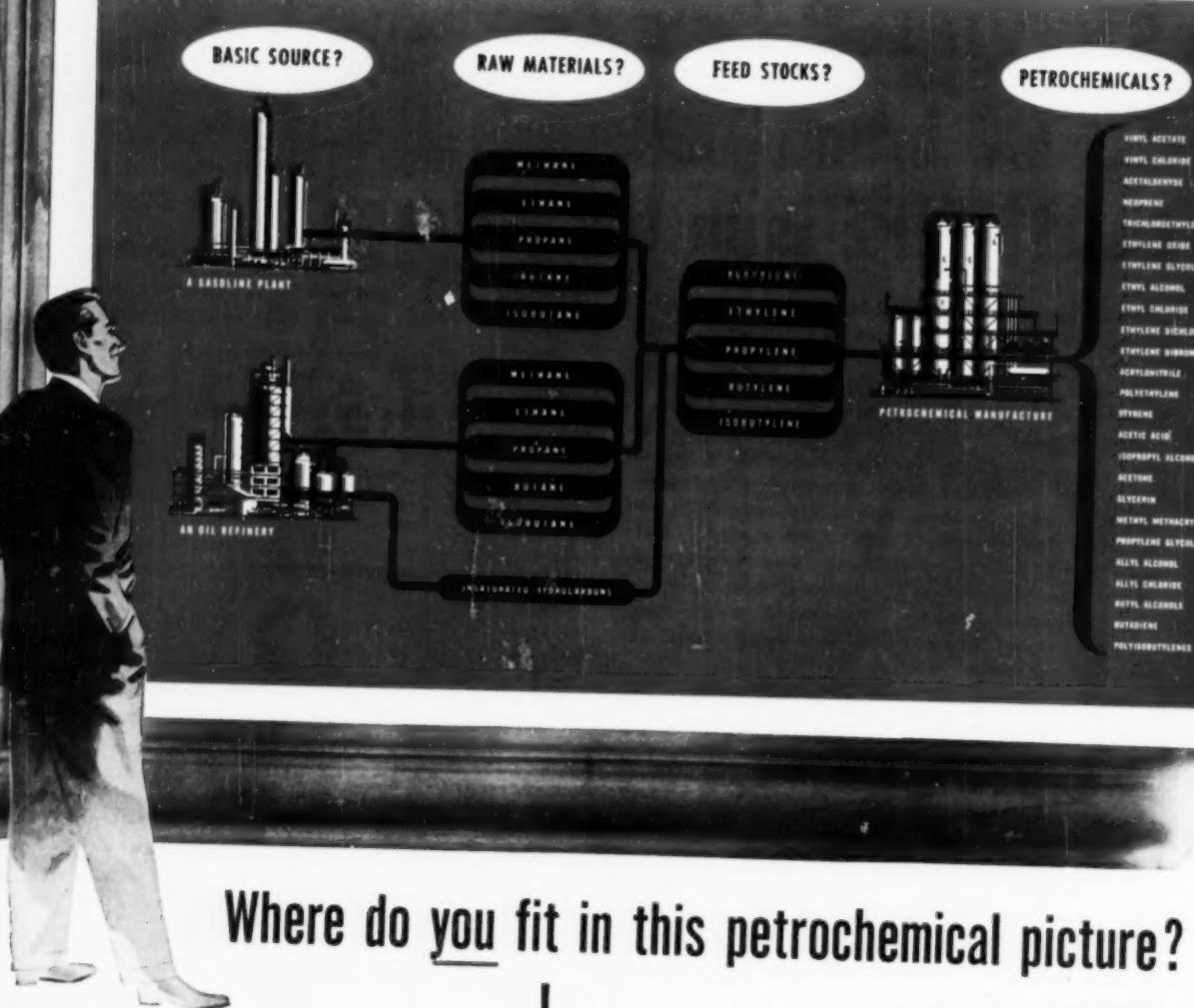
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Petrochemicals, the largest new factor in our ever-expanding world of chemicals, now account for nearly one-quarter of all U. S. chemical production. Despite this, it is estimated that only one-half of one percent of all present oil and gas production is being utilized as petrochemical feed stock. This opens up new opportunities for the oil and gas producer and investor.

If you own, operate, or have interests in an oil refinery or a gasoline plant, you should be aware of *your* potential as a supplier of petrochemical raw materials. This is particularly so when it is considered that the increase in value of an end petrochemical product may easily be four or five times greater than that of normal products realized from other hydrocarbon processing operations!

### Let Fluor assist you...

The proven abilities to design, engineer and construct complete plants and facilities for the petroleum, natural gas and petrochemical industries have established The Fluor Corporation as one of the nation's major engineering and construction organizations.

One call to Fluor will place men with broad and diversified experience in petroleum and chemical engineering technology and economy at your disposal. Let Fluor put these talents and facilities to work for you. You will be sure with Fluor!

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# DATA SERVICE

## EQUIPMENT

**1 • DEWATERING SCREEN.** Hendrick Mfg. Co. wedge-slot screen, made with small stainless steel bars, V-shape profile, effective for dewatering, drying, heavy media recovery, etc.

**2 • GRINDING MEDIA.** High density superporcelain balls and brick for grinding. McDanel Refractory Porcelain Co.

**3 • CONVECTION APPARATUS.** Beckman Instruments, Inc. new electrophoresis-convection apparatus. Separates proteins by isoelectric, modified isoelectric or differential transport method. Four principal units.

**4 • PROPORTIONED PUMPS.** Displacement of all liquids at every stroke, stroke adjustable while pump operates are new features of chemical proportioning pump by American Instrument Co., Inc. Stationary indicating scale, stainless-steel piston and cylinder assemblies, pressures 7500 to 30,000 lb./sq. in. Simplex and duplex styles.

**5 • CHART-PAK.** Chart-Pak kit for making organization and graphic charts. Contains plastic board, twenty-eight patterns on pressure-sensitive tapes, accessories for application and instructions for use. Chart-Pak, Inc.

**6 • SAFETY THERMOSTAT.** Low-temperature safety cut-off for use in ammonia-cooled heat-exchanger. Prevents freezing and possible spoilage if temperature control permits temperature to fall too low. Inverse Thermoswitch by Fenwal, Inc.

**7 • CUT-OFF VALVE.** Automatic gas cut-off valve from B. F. Goodrich Chemical Co. For use with natural and manufactured gas, to be placed on supply line in front of meter. -In

case of fire a plastic fusible link distorts at 165°F. closing valve.

**8 • GRAVITY SEPARATOR.** Specific gravity separator for laboratories, the Whippet V-80, by Sutton, Steele and Steele, Inc. Portable, weighs less than 100 lb.

**9 • INDUSTRIAL PUMP.** Designed with a scoop rotor and roller-type vanes new industrial pump for use where lime, talc, and other abrasive solutions are used. Sealed lubricated ball bearings insure resistance to continuous heavy radial loads. Cast iron with nylon or rubber rollers, self-lubricated, etc. Hypro Engineering Inc.

**10 • WATER ANALYZER LAMP.** For use with the Taylor water analyzer, lamp giving uniform daylight conditions. Measures 15½ in. x 9½ in. x 5½ in. Useful either long or short water analyzer tube. W. A. Taylor.

**11 • PLASTIC SAFETY GOGGLE.** Saf-I-Flex safety goggle, frame of clear, pliable vinyl, rolled edges, grid ventilation making goggle fog-free. Lens easily changed, optically correct. United States Safety Service Co.

**12 • MULTI-TUBE HEAT EXCHANGER.** Multitube sanitary heat exchanger from Niagara Filter Corp. Available

in several variations and metals for use with water, brine, steam, etc.

**14 • FLOWED-IN GASKET.** Dewey and Almy Chemical Co. new "flowed-in" gasket applied as liquid synthetic rubber or resin compound. Forced through nozzle to a spinning component part, it is baked to form solid rubbery gasket which will not fall off.

**15 • PNEUMATIC CONTROLLER.** Catalog from Fischer & Porter Co. covering (Pneumatrol) pneumatic controller for flow rate, differential pressure, liquid level, and temperature applications.

**16 • PYRENE FOAM.** For oil refineries and the industrial chemicals field, pyrene foam as a protection against fire hazards from alcohol and oil. An all-purpose foam, effective life greater than other stable foams. U.L. approved. Pyrene Mfg. Co.

**17 • VENTURI NOZZLE.** Saran-lined venturi flow nozzle from Builders-Providence, Inc. Used for metering and control of corrosive fluids. Sulfuric acid, nitric acid, ethyl alcohol, and other solvents.

**18 • PACKAGED-FEED SYSTEM.** Packaged-feed system from Milton Roy Co. Reduces field piping and offers saving in installation time and space.

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# DATA SERVICE

Consists of 50-500 gal. carbon steel solution tank mounted on controlled volume pump. Simplex and Duplex models, ten types of metal. Capacities to 300 gal./hr., pressures to 5000 lb./sq.in.

**19 • MIXER.** For industries mixing a number of products in cans or drums, such as blending, thinning and tinting of paints, varnish and other chemicals, a new type change-can mixer from Industrial Process Engineers.

**20 • SPARGER NOZZLES.** Sparger nozzles made from Haveg by Schutte and Koerting Co. For use in tank heating of liquids. Molded from Haveg 60 they are resistant to acids, salts, and solvents. Also made from Haveg 41.

**21 • TEMPERATURE TRANSMITTER.** The Swartwout Co. temperature transmitter for specific use with the all-electronic Swartwout Autronic control. Flexible and adaptable to special operations.

**22 • MIDGET THERMOSTAT.** A redesigned midget Thermoswitch released by Fenwal Inc. O.D. only  $\frac{1}{4}$  in. For applications requiring precision temperature control or overheat detection in solids, gases,

liquids with limited space. Range 50° to 450° F., sensitivity 0.1° F.

**23 • OIL RECLAIMER.** Hilliard Corp. introduces new line of oil reclaimers directly connected to turbine reservoir, or oil tanks for continuous operation, or oil tanks for batch operation.

**24 • TELSTOR LEVEL INDICATOR.** For measuring most liquids, viscous liquid or granular solids, in tanks, bins, hoppers, etc. Fielden Instrument division, Robertshaw-Fulton Controls Co. has a new electronic instrument, Telstor, for continuous level measurement.

**25 • CENTRI-CLEANERS.** The Bauer Bros. Co. centri-cleaners for removing dirt from fibrous pulps of low consistency. Savings in pulp preparation through use of dirty, rough or unbarked woods. Operation, theory and practice, applications, etc., covered.

**26 • INSPECTION EQUIPMENT.** For ultraviolet production and processing techniques, packaging operations, etc. Blak-Ray inspection equipment from Ultra-Violet Products, Inc. Detects decay and fungus in agricultural products, flaws in castings, flaws and dye variations in textiles, markings on fabrics or other materials.

**27 • DISTILLATION TRAYS.** Turbogrid distillation trays new with Shell Development Co. and used as contacting trays for distillation columns. Advantages, design, diagrams, and all details given in leaflet.

**28 • CONDENSERS, HEATERS AND COOLERS.** Bulletin from Manning & Lewis Engineering Co. describes heaters, condensers and coolers. Table of sizes, weights, dimensions, diagrams, etc., given.

**29 • TEST GAGE.** For periodic check of pressure instruments, test gage aids in saving process fluid and reduction of operating costs. Guaranteed accurate within  $\frac{1}{2}$  of 1% and furnished in ranges of 0-30 Hg vac. up to 0-10,000 lb./sq.in.g. From Foxboro Co.

**30 • MOTOR CONTROL.** A pneumatic remote control for Varidrive motors announced by U. S. Electrical Motors, Inc. Valves available are pedal, lever, cam or wheel, operates on air pressure of either 60 or 100 lb./sq.in.; rapid change of speeds possible.

**31 • HEAT-EXCHANGER TUBES.** Aluminum heat-exchanger tubes from Aluminum Co. of America. Comprehensive brochure includes tables, illustrations of products, diagrams, advantages, applications, etc. Two sizes 1 in. O.D. with .049 in., and .065 in. wall thickness.

**32 • SHUT-OFF VALVE.** Shut-off of anhydrous ammonia or liquefied petroleum is instantaneous by new sentry-balanced diaphragm excess-flow shut-off valve from McRae Valve Corp.

**33 • TORQUE BALANCES.** Ohaus Scale Corp. precision torque balances made in Holland. Feature is a patented torsion system eliminating mechanical axle friction. Capacities 1 mg. to 20 mg., sensitivities .002 mg. to .02 mg.

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# DATA SERVICE

**34 • PLASTIC DUCTS.** Line of solid plastic corrosion-proof fume ducts, hoods and accessory equipment announced by Heil Process Equipment Corp. Construction offered in polyester glass combinations. Temperatures in excess of 200° F. Variety of shapes.

**35 • PUMPS AND POWER UNITS.** Newly designed to develop high-fluid pressure from low-air pressure, new series of heavy duty, air-hydraulic pumps and power units. Descriptive literature and prices available from Ledeen Mfg. Co.

**36 • SIGHT GLASSES.** Flow, color, turbidity, etc., observed with new sight glass from Grand Machine & Tool Co. Flanged or screwed types, constructed of heavy-gage rolled stainless. For five-, ten- and forty-piping systems.

## CHEMICALS

**40 • TANK LINERS.** Unplasticized polyvinyl chloride tank liners offered by American Agile Corp. Fully welded, furnished with drain and overflows, include Agilene or Agilide pipe flanges, fittings, etc. All sizes and shapes, wall thickness to 1 in.

**41 • CORROSION-RESISTANT TAPES.** Minnesota Mining & Mfg. Co. two corrosion-resistant tapes for pipe-wrapping. Polyvinyl-chloride types, eliminate need for tar pots and other equipment. Give pinhole-free cold coating, easily applied. Reference table listing need for specific pipe available.

**42 • MODIFIED POLYSTYRENE.** Improved shock and heat resistance in a new modified polystyrene from chemical division of Koppers Co., Inc. For toys, refrigerator parts, battery cases, etc.

**43 • CHEMICALS.** A 112-page edition covering entire chemical line of Stauffer Chemical Co. Loose-leaf, data on all products, tables on gravity, viscosity, etc.

**44 • FURNACE BLACK.** Godfrey L. Cabot, Inc., announcement of Vulcan 9 oil furnace black. High-tensile strength.

**45 • SYNTHETIC COATING.** Corrosion-resistant for wood, masonry, and metal surfaces, new synthetic coating from Monroe Co., Inc.

**46 • AMBERLITE ION RESINS.** From Fisher Scientific Co., six Amberlite ion resins in laboratory grade. Use in laboratory exchange columns, synthesis, etc.

**47 • STYRENATED LINSEED OIL.** Linstyrol, new drying oil based on linseed oil and styrene from Spencer Kellogg & Sons, Inc. Completely miscible with solvents and refined drying oils. Dries in 15-20 hr., hard and clear film.

**48 • CYCLODEX.** Accelerated curing of latex emulsions by use of Cyclo-dex, a new catalyst of Nuodex Products Co., Inc. Improves adhesion, in-

creases film toughness, reduces injury from rubbing, scuffing, etc.

**49 • CONCRETE COLORS.** Reardon Industries, Inc. development for coloring concrete. To encase lines carrying electric current, brines, acids, and other liquids.

**50 • ORGANIC CHEMICALS.** Ten new chemicals announced by Distillation Products Industries, division of Eastman Kodak Co. Include 2-(o-Hydroxyphenyl) benzoxazole reagent for gravimetric determination of cadmium; benzenephosphonic acid; benzenephosphorous acid; tert.-Butylamine BP 44-45°, and others.

**51 • ALIPHATIC NITROGEN COMPOUNDS.** Carbide and Carbon Chemicals Co., new 44-page illustrated book details thirty-five aliphatic nitrogen compounds. Used for emulsifying, neutralizing, dissolving, etc. Physical properties, specifications, etc., as well as bibliography included. Section on test methods.

**52 • METHYLAMINES.** Two data sheets from Commercial Solvents Corp. on monomethylamine, dimethylamine, trimethylamine and furfurylamine. Formulas, properties, specifications, etc.

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**53 • PETROLEUM RESIN.** Piccopale, polymerized petroleum resin developed by Pennsylvania Industrial Chemical Corp. Available as solid, flaked and in solution. For chemical, textile, pulp and paper, petroleum, etc., industries. Melting point 70° to 100° C. Brochure.

**54 • FIREFAX.** Pyrene Mfg. Co. Firefax an occasional publication covers news concerning fire protection with its various units, extinguishers, pyrene foam, etc.

## BULLETINS

**55 • FLEXIBLE PIPE CLEANING.** Bulletin from Flexible Pipe Cleaning Co. describes and illustrates various hand tools and working heads for all conditions of pipe. For mechanical rodding of phone and electric ducts, fish wire pullers, speak heads, rod guide jacks, etc.

**56 • CHECK VALVES.** Tilting disc check valves of iron, bronze, and steel for pressures up to 3000 lb./sq.in. described in Chapman Valve Mfg. Co. bulletin. It covers dimensions, details of construction, types, etc., of valve which operates either horizontally or vertically.

**57 • COOLING TOWERS.** Brochure from C. H. Wheeler Mfg. Co. on operation and maintenance of mechanical draft-cooling towers. Application and performance, placing tower in operation, maintenance, etc., reviewed in detail.

**58 • SILICONE RUBBER.** A reference file for designers plus information for laymen on silicone rubber from

Dow Corning Corp. Applications include gaskets, seals, diaphragms, electrical insulation hose, etc. Bulletin includes temperature, strength, resistance and hardness charts, etc.

**59 • INDUSTRIAL MIXERS.** Industrial mixers for the glass, fertilizer, refractories, chemicals, etc., industries, open or dust-sealed. Bulletin from Worthington Corp. describes both open and dust- and fume-proof design. Specifications, dimensions, etc.

**60 • PLASTIC PIPE AND FITTINGS.** Kraloy Plastic Pipe Co., Inc. leaflet on plastic pipe and fittings. Made of light weight resin. Noncorrosive, nonconductor of electricity, no affinity for waxes, or paraffin, requires no wrapping, low installation cost.

**61 • CENTRIFUGAL COMPRESSORS.** Single stage 30-600 hp. pressures 1½-3½ lb./sq.in. centrifugal compressors by American Blower Corp. Ratings applications, speeds, functions, etc.

**62 • SUPER-REFRACTORIES.** Materials of construction offering resistance to corrosion and abrasion, high hot strength, chemical inertness and wide range of thermal conductivities in bulletin from Carborundum Co. Withstands 3000° F.

**63 • FORK TRUCKS.** Yale & Towne Mfg. Co. new drum- and barrel-handling attachment for its fork trucks. Handles drums of any head or rim size. Easily attached. Drums can be tiered at maximum fork height without use of pallets.

**64 • HEAT EXCHANGER.** Delanium graphite block cubic heat exchanger from Delanium Carbon Corp. High thermal conductivity. Thermal con-

ductivity 40 B.t.u./(hr.) (sq.ft.) (°F/ft.). Chemically resistant, high compression strength. Bulletin illustrated; charts, etc.

**65 • VALVE CONTROLLER.** Fisher Governor Co. on Positrol valve controller. Gives valve-position stability in large or small changes without cyclic effect of over- and under-position control. Operating principle diagrammed, specifications, dimensions, etc.

**66 • OXYGEN-NITROGEN GENERATORS.** Generating equipment for production of oxygen, nitrogen and other gases. Two types both with low-, medium-, or high-pressure cycles. Used in petrochemical, glass, chemical, etc., industries. Air Products, Inc. bulletin.

**67 • NEOPRENE SYSTEM.** Cold easy bonding to equipment of uniform sheet cured Neoprene. From Gates Engineering Co. Film thicknesses  $\frac{1}{16}$ - $\frac{3}{16}$  in. available in single application.

**68 • KONCENTRIK FITTINGS.** Stainless steel fittings with teflon seals from Special Screw Products Co. Variety of sizes and tube combinations, diagrams, sizes, tee combinations, etc., in bulletin.

**69 • LABORATORY APPARATUS.** Scientific Glass Apparatus Co. "What's New for the Laboratory" series Twenty-seven items featured in bulletin photographically illustrated. Details of sizes, prices, etc.

**70 • DURANT ANCHOR.** Durant Insulated Pipe Co., insulated anchor for underground insulated-pipe systems conveying hot or cold liquids, or gases. Construction eliminates contact between anchor plate and pipe. Plate insulated from pipeline both thermally and electrically.

**71 • ALLOY EQUIPMENT.** Alloy Fabricators, division of Continental Copper and Steel Industries, Inc. line of corrosion-resistant equipment for chemical oil, food, textile industries, etc. Covered are coolers, kettles, dust collectors, etc. Specific information on specially designed equipment.

**72 • OXYGEN ANALYZER.** Arnold O. Beckman, Inc. announces model G oxygen analyzer. Used in boiler plants, chemical processes, oil refineries, medical research, etc. Automatic operation, temperature- and flowrate-independent, wide range.



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## ANNUAL MEETING

this country and is selling rubber in competition with private producers in the United States and in other parts of the world. If this is not socialism, surely it is something perilously close to socialism," he declared.

Collyer called the attention of the chemical engineers to the fact that the government now is spending tax money to pay for 56 per cent of all research being done in this country, whereas 10 years ago it accounted for 36 per cent. "If this rate of increase should continue," he said, "private industry may soon be squeezed out of research, either because government has a monopoly on the talent or because the discoveries have been socialized."

Collyer also questioned the recommendations made by the President's Materials Policy Commission in June, 1952, that governments in effect, "control the supply and flow of the world's raw materials."

These recommendations, he said, would authorize the government to enter into management contracts for foreign materials expansion, and to establish a permanent agency to: (1) make long-term purchase agreements, including price guarantees; (2) provide funds for production loan assistance, and (3) enter into contracts or make loans which provide for sharing of profits with government under certain circumstances.

This, he said, would substitute the judgment of government planners at home and abroad for "the judgment of the market place," and such action "would strike a blow at the very heart of our country's competitive economy."

Collyer said that the Commission's report includes estimates as to the materials situation 25 years ahead, and he doubted that such recommendations could be made for the 1970-1980 period "with any useful degree of accuracy."

### Technical Discussion

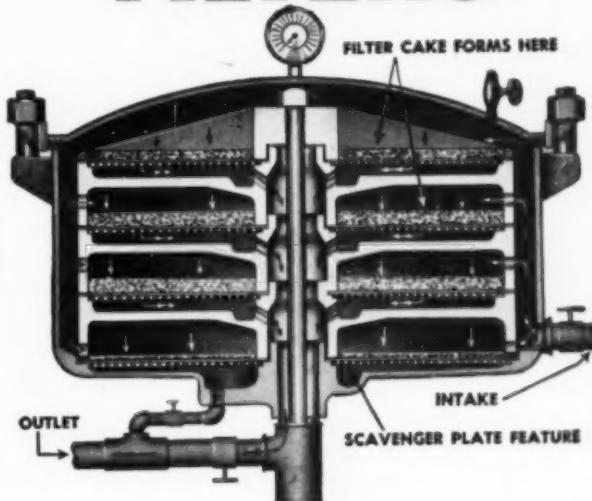
Two major technical addresses, now both Institute traditions, were given at Cleveland. One was the fourth annual Institute Lecture delivered by Prof. W. R. Marshall, Jr., of the University of Wisconsin, on "Spray Drying and Atomization"; the other, the annual Professional Progress Award lecture by Prof. R. H. Wilhelm of Princeton University, who discussed "Rate Processes in Chemical Engineering." Professor Marshall's talk will be published as a Chemical Engineering Progress Monograph, and the Wilhelm talk will probably appear in the February issue of "C.E.P."

The symposia represented a variety of subjects beginning with an applied ther-

(Continued on page 38)

**Forget your troubles with filter cake stability, cracking, slipping or breaking when you use . . .**

# SPARKLER HORIZONTAL PLATE FILTERS



The positive stability of the filter cake in Sparkler Horizontal Plate Filters gives a consistent uniform quality of filtration regardless of variations in pressure or flow interruption, even with complete shut down of the filtering operation.

No fibrous material is required to hold a pre-coat on the horizontal plates. Even a very thin pre-coat can be applied and a low density cake built up with low pressure filtering resulting in a greater flow rate than is possible where pressure is required to hold the cake in position.

Any kind of filter media, paper, cloths, or screens with any grade of filter aid can be used with maximum efficiency because the problem of cake stability is never a consideration with Sparkler Horizontal Plate Filters.

Fine sharp filtration is obtained right from the start and continued up to the end of the filtering cycle.

The filter cake built up on a Sparkler Horizontal Plate is always uniform in thickness and porosity over the entire plate. Flow is with gravity, and the filter aid is floated into position and distributed evenly over the entire surface.

This is why users of Sparkler Filters are free from filter cake trouble.

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E. W. Comings (right), Purdue University, chairman of the High Pressure symposium with A. V. Slack who presented a paper.

R. H. Wilhelm, Princeton University, won the Professional Progress Award. J. Henry Rushton, Illinois Institute of Technology, won the William H. Walker Award. Thomas Baron won the Junior Award, along with L. G. Alexander of Oak Ridge National Laboratory.



Speakers at the Applied Thermodynamics Symposium were, left to right: R. L. Pigford, Wayne C. Edmister (chairman), J. M. Nelson, S. T. Hadden, C. L. DePriester, and D. E. Holcomb.



C. D. Luke, chairman of the Filtration Symposium, with the speakers on his panel. F. M. Tiller, Lamar State College; William L. Ingmanson, Institute of Paper Chemistry; and H. P. Grace, Du Pont Co.



Speakers at a general technical session. Left to right: Norman Barson, Iowa State College; B. F. Smith, Oklahoma A. & M.; R. C. Phillips, Stanford Research Institute; Richard Lester, General Foods Corp.; and John W. Clegg, Battelle Memorial Institute and chairman for this session.



Additional Filtration Symposium speakers included: E. A. Ulrich, Niagara Filter Corp.; F. M. Tiller, chairman, Lamar State College; C. D. Luke, Syracuse University; E. A. Kane, Cuno Engineering Corp.; and B. F. Ruth, Iowa State College.



R. L. Savage of Case Institute was program chairman for the annual meeting.



W. R. Marshall, University of Wisconsin, delivers the Fourth Annual Institute Lecture. His subject was "Spray Drying and Atomization."



J. M. Smith, Purdue University, delivered a paper "Heats of Mixing of Liquids."

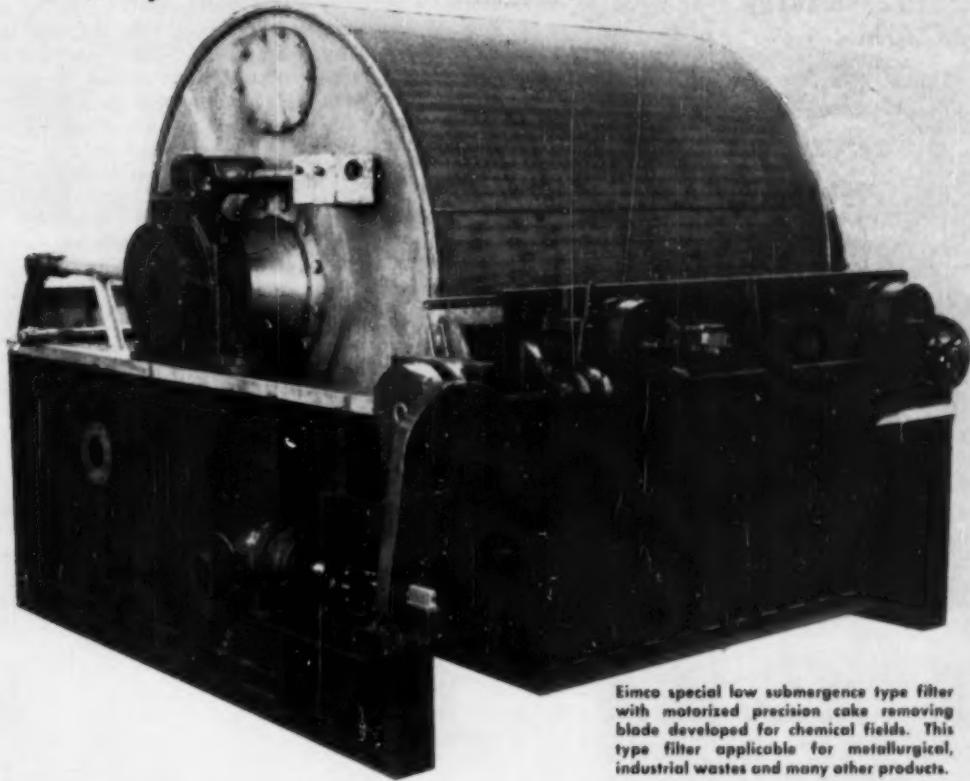


H. G. Drickamer, University of Illinois, spoke on the uses of radioactive tracers.



Edgar L. Piret, University of Minnesota.

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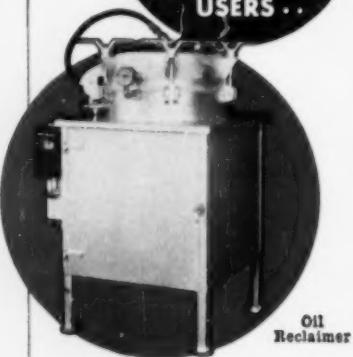
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## ANNUAL MEETING

modynamics symposium under the direction of W. C. Edmister of the California Research Corp., Richmond, Calif.; another on "Modern Statistical Methods in Chemical Engineering," with C. Daniel of the research laboratory of U. S. Steel Corp., presiding; E. W. Comings, head of undergraduate engineering school, University of Illinois, was chairman of a high-pressure symposium along with B. F. Dodge of Yale University. There was an important filtration symposium, put together by F. M. Tiller, Lamar State College of Technology, Beaumont, Tex., and a human relations confab under the direction of R. L. Demmerle of General Aniline and Film Corp., vied with several sessions of general papers for the interest of the chemical engineers.

The chemical engineers were given a view of how modern chemical engineering is solving problems on every front, by Dr. Robert D. Ingebo of the National Advisory Committee for Aeronautics. Dr. Ingebo reported on a study of one of the factors causing high fuel consumption in jet engines, and told the meeting that inefficient evaporation of the liquid fuel in jet engines in forming combustible vapor and air mixtures, contribute to high fuel consumption. His study was titled, "The Effect of Pressure and Evaporation of Drops in Gas Streams." The conditions of the Ingebo tests simulated operation of a jet engine from sea level to altitudes of 60,000 ft.

A warning to chemical engineers that the proper design of pumps used in chemical engineering should not be overlooked, was made by R. L. Jacks, design engineer, Esso Standard Oil Co. (La.). Mr. Jacks reported on "Process Design of Pumping Equipment." He said that with the great industrial expansion in America today, proper design of pumps is vital. He continued that good design involved the correct evaluation of the problem and adequate specifications of the requirements. To design a new pump properly, he said, so that it might be specified adequately to the manufacturer, six major points must be covered: general identification, process requirements, suction conditions, discharge conditions, design factors and limitations, and any special features.

At the symposium "Human Relations," the keynote address was delivered by R. L. Demmerle, assistant to the director of administration, General Aniline and Film Corp. Demmerle said that the need for an understanding of the human factors springs from two major trends in the chemical industry: (1) the movement of technically trained men to posts where their principal job demand is the direction of people, and (2)

the interest of nontechnical groups and the investing public in the chemical industry. He claims it is imperative that the technical man become an ambassador of industry to the lay world.

R. S. Schultz, director, Industrial Relations Methods, Inc., told why chemical engineers succeed or fail with people, and stressed that the real factors of success are found in such characteristics as personality, attitude, motivations, etc. He gave suggestions on how a chemical engineer might best improve personality characteristics in any category in which he feels he is deficient.

Prof. Paul Pigors of the Massachusetts Institute of Technology said that the aloofness of technical men from the problems of working management in dealing with people, has inhibited their status. Professor Pigors went into detail about developing the skill of working in harmony with others and resolving conflicts which exist between those doing the work and their supervisors.

Dr. Carl F. Prutton, president, Mathieson Development Corp., and a former head of the department of chemistry and chemical engineering at Case Institute of Technology, gave an opening paper on the chemical industry in Cleveland. He predicted that a healthy future expansion could be expected in this area, and he traced the growth of Cleveland back to 1845.

Today's vast industrial structure, he said, was "reared on a shaky foundation of whiskey and sodium bicarbonate," adding that this "was a happy combination, in a way, as it could involve a steady demand for both commodities by the same consumer." In 1845 the gross income of this limited industry was \$12,000.

The advent of steel and petroleum refining in Cleveland between 1850 and 1870 was credited by Dr. Prutton with giving Cleveland its first real industrial impetus. From this time to the early 1900's there was a steady influx of varied industries depending upon and supplying these basic industries.

Although Cleveland is a great metal producing and fabricating center, it has had a recent spurt in chemical industries. In 1939, continued Dr. Prutton, government figures showed 187 chemical and related industries in the metropolitan area comprising Lake and Cuyahoga counties. Persons numbering 8,128 were employed and produced goods valued at about \$110 millions. By 1947 this had grown to 504 plants employing 29,093 and producing products valued at \$525 millions.

Dr. Prutton pointed to the "truly fantastic" growth in chemical producing capacity between Fairport and Ashtabula. The so-called Chemical Shore is today one of the world's great chemical centers.

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# CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

## Applicants for Active Membership

Adams, Nelson R., New York, N. Y.

Bortholomew, Paul H., Skokie, Ill.

Brennan, James J., Jr., Bartlesville, Okla.

Buchanan, Robert L., Wilmington, Del.

Catterall, William E., Linden, N. J.

Clear, C. G., Wood River, Ill.

Coons, Waldo M., Jr., Wilmington, Del.

DeBiase, Robert, Staten Island, N. Y.

Dickey, Wm., San Jose, Calif.

Donnelly, Harold Geo., Dearborn, Mich.

Ela, Benj. W., Jr., Berkeley, Calif.

Estep, James W., Worland, Wyo.

Fey, Vernon O., Denver, Colo.

Florine, R. E., Seattle, Wash.

Fraser, Vert C., Bay Village, Ohio

Govier, G. W., Edmonton, Alberta

Hall, E. B., Wilmington, Del.

Harvey, J. K., Charleston, W. Va.

Kopecki, Alfred F., Flossmoor, Ill.

Klein, Maurice, Savannah, Ga.

Kunkel, Karl E., Grand Island, N. Y.

Lacey, Joseph I., Niagara Falls, N. Y.

Lawless, Grant P., Racine, Wis.

Lawrence, Philip H., Avon Lake, Ohio

Lewis, Nelson W., E. Orange, N. J.

Linde, Frederick A., Mt. Lebanon, Pa.

Lofton, Wm. M., Jr., Homewood, Ala.

Maerker, John B., Secane, Pa.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before February 15, 1953, at the Office of the Secretary, American Institute of Chemical Engineers, 120 East 41st, New York 17, N. Y.

Brunsting, Elmer H., Cincinnati, Ohio

Capobianco, Michael F., Brooklyn, N. Y.

Chadwick, John L., Beaumont, Tex.

Childers, Howard D., Manhattan Beach, Calif.

Church, Don M., Houston, Tex.

Clark, Ralph L., Marblehead, Mass.

Cole, T. Phillip, Wilmington, Del.

Coleman, Charles N., Baytown, Tex.

Cooper, William G., Texas City, Tex.

Cotton, W. S., Montreal, Que., Canada

Czarnecki, Raymond C., Buffalo, N. Y.

Davis, Irwin A., Philadelphia, Pa.

Deacon, Thomas Henry, Gary, Ind.

Deisler, Paul F., Jr., Berkeley, Calif.

Demos, Anthony C., Bridgeport, Pa.

DiBona, Robert James, Rochester, N. Y.

Dunlevy, Charles M., Pottstown, Pa.

Engel, Alfred J., Berkeley, Calif.

Finch, Harold L., Texas City, Tex.

Ford, Fred A., Texas City, Tex.

Freda, Alfred A., E. Boston, Mass.

Fuller, O. M., Jr., Charleston, W. Va.

Granger, Peter, Dunbar, W. Va.

Graves, Richard D., Pittsburgh, Pa.

Greek, Charles D., Texas City, Tex.

Gross, Sidney, Seattle, Wash.

Gruwell, Raymond G., New York, N. Y.

Gunter, Chester Gene, Austin, Tex.

Hacker, Robert F., St. Louis, Mo.

Hamilton, Lorie W., Jr., Texas City, Tex.

Hatch, A. C., Longmeadow, Mass.

Hoxton, Manford R., Texas City, Tex.

Hensel, Walter E., Racine Wis.

Holstedt, Richard A., Chicago, Ill.

Jordan, Leon D., Cincinnati, Ohio

Kendrick, Thomas R., III, Pittsburgh, Pa.

King, Bennie J., Houston, Tex.

King, William G., Baytown, Tex.

Koloseus, Edward J., Massapequa, N. Y.

## Applicants for Associate Membership

Chang, Yi-Chung, Tulsa, Okla.

Hall, Joseph T., Jr., Texas City, Tex.

Noisier, Henry G., Philadelphia, Pa.

Reif, Henry E., Drexel Hill, Pa.

Swanton, Walter F., Avon, N. Y.

Van Blaricom, R., Huntington, W. Va.

Van Dyke, Richard J., Racine, Wis.

## Applicants for Junior Membership

Anderson, Louis J., Army Chemical Center, Md.

Austin, Robert D., Tampa, Fla.

Bailey, Robert S., W. Lafayette, Ind.

Bark, Wendell G., Baton Rouge, La.

Biesiadecki, Joseph P., Newark, N. J.

Biggers, M. W., Lake Jackson, Tex.

Birch, Robert W., Savannah, Ga.

Blandy, D. E., University City, Mo.

Bowman, Charles E., Texas City, Tex.

Bremer, Alvin B., Nanuet, N. Y.

Brown, Thurman E., Corpus Christi, Tex.

(Continued on page 42)

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 and one-piece belted gland. Sizes  
 4 to 8 in. have conventional belted  
 bonnet joint and two-piece belted  
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 bonnet joint and  
 flanged ends, Sizes 5, 6  
 and 8 in.  
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 and 12 in. Belted  
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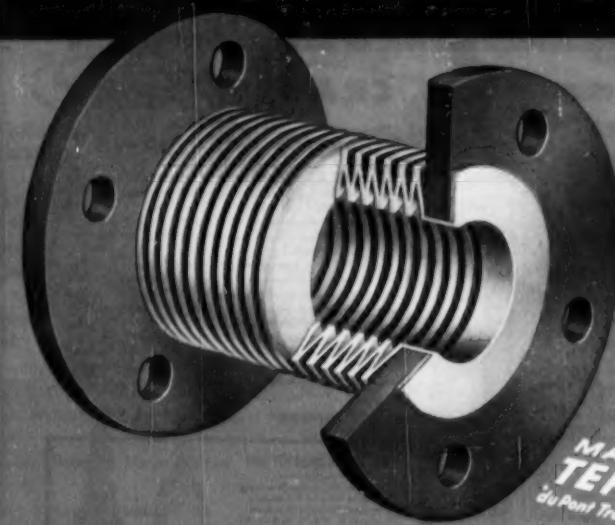


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### CANDIDATES

(Continued from page 40)

Krause, Walter P., Austin, Tex.  
Kutler, Andrew A., New York, N. Y.  
Lapides, Melvin, Cincinnati, Ohio  
Larkin, James C., Jr., Overland, Mo.  
Lellouche, Gerald S., Laurelton, N. Y.  
Levenspiel, O., Corvallis, Ore.  
Levoy, Myron W., Lafayette, Ind.  
Lewis, Donald C., Everett, Mass.  
Liles, Arthur William, Pacasset, Okla.  
Martin, Howard W., Texas City, Tex.  
Martinson, S. Alan, Buffalo, N. Y.  
Matteson, Robert A., Marcus Hook, Pa.  
McCool, Edward J., Detroit, Mich.  
McCracken, Robert Jene, Pittsburgh, Pa.  
McDonnell, J. T., Tulsa, Okla.  
McDonough, William D., Cambridge, Mass.  
McKinstry, John R., Akron, Ohio  
Meyer, Donald B., Texas City, Tex.  
Miner, Clarence Crosier, Jr., Texas City, Tex.  
Mobley, Burton L., Houston, Tex.  
Moore, Donald A., Linden, N. J.  
Moore, Joe F., Baytown, Tex.  
Moore, Kenneth G., Port Washington, N. Y.  
Ore, Fernando, Seattle, Wash.  
Pagan, Ervin W., Rock Hill, Mo.  
Perillo, Louis B., Maple Hts., Ohio  
Plow, A. E., New York, N. Y.  
Politizer, Irwin, Army Chemical Center, Md.  
Pollock, Andre W., Chester, Pa.  
Ralls, W. O., Jr., Savannah, Ga.  
Ruby, Charles L., Richmond, Calif.  
Saphier, Lawrence, Midland, Mich.  
Sandvig, Robert L., Boulder, Colo.  
Shirley, Thomas E., Texas City, Tex.  
Souder, Wilmer, Jr., Pottstown, Pa.  
Stephenson, Kennard F., Jr., Babylon, N. Y.  
Thomas, Lee W., Wilmington, Del.  
Thorn, Frank H., Topeka, Kan.  
Truitt, W. Bond, Ft. McClellan, Ala.  
Turner, John A., Baltimore, Md.  
Valvoda, Thomas A., Jr., Chicago, Ill.  
Van Ness, Hendrick C., Lafayette, Ind.  
Vaughn, Robert E., Cambridge, Mass.  
Warren, T. Wayne, Baytown, Tex.  
Weeks, Charles A., Aruba, Netherlands, W. I.  
Weist, Robert G., Texas City, Tex.  
Westerman, Howard W., Wellington, Mo.  
Whipple, John C., Richland, Wash.  
Wieland, George E., Jr., Bethlehem, Pa.  
Williams, Luther L., Danville, Pa.  
Worth, John L., Chadds Ford, Pa.  
Young, Clayton C., Rahway, N. J.

### COMPRESSED GAS ASSOC. MEETS THIS MONTH

The Compressed Gas Association, Inc., will hold its fortieth annual meeting at the Waldorf-Astoria, New York, Jan. 26 and 27, 1953.

Technical Sessions will be held on Monday afternoon, and Tuesday morning. Committee meetings will be held Monday morning. The annual business meeting of members will be held Tuesday afternoon.

## "SCHOOL FOR TEACHERS" AT T.V.A.

The second "school for teachers" in the Southeast was held at the Tennessee Valley Authority installation in Muscle Shoals, Ala., on Nov. 21, 1952. Organization of the school on the college side was handled by Frank A. Anderson, head of the department of chemical engineering at the University of Mississippi, and organization of the program at TVA was under the direction of A. V. Slack, staff chemical engineer at the Authority. The subject for discussion, introduced by K. L. Elmore, chief of TVA research branch, was "Applications of Catalysis in Industry." Mr. Elmore also presented a review of modern theory of catalysis.

The numerous applications of catalysis in industry were reviewed by J. S. Cromeans, director of technical service, catalyst department, Girdler Corp., Louisville, Ky. Mr. Cromeans pointed out that knowledge of catalysis has progressed to the point where catalysts, in some cases, can be tailored to cover quite a narrow reaction acceleration range out of a large number of competing reactions.

Special laboratory techniques used in research on catalysts were reviewed by E. O. Huffman, TVA chemist. This was followed by an account of TVA catalyst manufacturing experience by R. B. Burt, chief of the TVA plant chemical control branch. The final discussion by J. C. Barber, assistant chief of the plant chemical control branch, described the four plant catalytic operations at TVA, with emphasis on problems of maintaining catalyst activity.

After a discussion session, the visiting professors were taken on a tour of the operating plants and the catalyst manufacturing installation. Seventeen professors from six colleges and universities of the area attended the sessions.

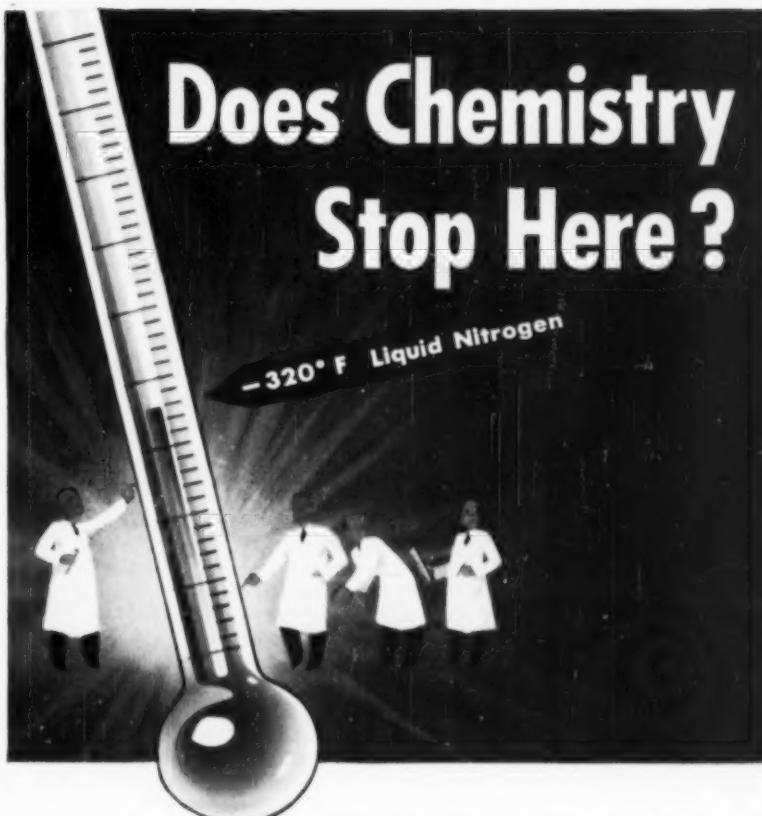
The first "school for teachers" was also held at TVA on Nov. 9, 1951 (see "C.E.P.", October, 1951, p. 48). This novel idea of the industry-advocated school, sponsored by the Chemical Engineering Projects Committee of A.I. Ch.E., has been proving worth while to student and instructor.

## CANADIAN STUDENT ENGINEERS UP

Registration of first-year engineering students at Canadian universities is 34% higher this year than last, according to an annual survey recently completed by the Engineering Institute of Canada.

This survey indicates that 2865 first-year students registered in engineering courses for 1952-53, compared with 2105 for 1951-52 and 1874 for 1950-51. Approximately 50% more students are now

(Continued on page 46)



Normally when we think of chemistry, we think of chemical activity at room temperature and above. Yet it is possible that important anomalous behavior will appear in a very small temperature interval... perhaps near Absolute Zero.

Although research near absolute zero (-460°F) is relatively new, it is contributing daily to the metallurgists' understanding of the properties of metals... And physicists have already discovered promising low-temperature phenomena, such as superconductivity, and are now looking toward their practical application.

At present, low-temperature chemistry is mostly an interesting combination of words. But this is changing. Chemicals which are extremely reactive at ambient temperature may conceivably be stabilized at low temperature. Knowledge of what happens at extreme low temperature can be of particular value to chemists as a key to the explanation of high-temperature reactions.

Today, facilities for extreme low temperature are part of a well-equipped laboratory for virtually all fields of research. Write for descriptions of low-temperature equipment and applications—Bulletin CEP 22-1.

Arthur D. Little, Inc., has developed many new methods for low-temperature research, especially in Cerium, rare earths, superconducting helium and the like. It is now possible to obtain temperatures as low as 10 degrees below Absolute Zero.

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## NEW TECHNIQUE FOR FIELD ERECTION

A new wrinkle in erection practices is reported by the Catalytic Construction Co. as having "cut costs and time" in the installation of new refining facilities at the El Paso plant of the Standard Oil Company of Texas.

The new equipment includes a synthetic crude unit and a Houdriflow catalytic cracking unit—each rated at 11,500 bbl./day—a 7,555 bbl./day vacuum flash unit, a gas recovery unit, and an alkylation plant.

The new erection procedure, illustrated above, was the use of the stairwell and elevator shaft of the catalytic cracking unit as a pedestal for the guy derrick. This saved the time and cost of a separate structure, which would ultimately have to be dismantled.

Orthodox construction practice would have called for a guy derrick to reach a height of 360 ft. The foundation, erection charges and rental or depreciation of a derrick pedestal for such service costs in the range of \$50,000 to \$65,000.

The use of the stairwell and elevator shaft offered an alternate possibility, with the added advantage that none of the cost involved in the guy derrick pedestal erection would have to be written off as cost of construction. This stairwell, a substructure of reinforced concrete 45½ ft. above grade and a steel structure 17 × 21 ft., rising more than 300 ft. above the concrete pedestal, had to support a catalyst elevator 300 ft. long, on a head shaft 311 ft. above grade.

These design conditions gave a structure which, by the use of guys, would adequately support the required construction derrick with its 100-ft. boom and 25-ton capacity. However, under these conditions, with the limited working area, and by reason of the pedestal itself being guyed, it was clear that each piece of equipment would have to be raised to the top of the structure and rotated 90° before being lowered into place.

## A.I.C.H.E. MEMBERS ON STATE BOARDS

According to a tabulation made by Alex C. Burr, chief of the fuels technology division, U. S. Bureau of Mines, Jamestown, N. D., chemical engineers are playing an increasingly important

part in the state registration of professional engineers. Mr. Burr sent in the following list of members of A.I.C.H.E. who are serving on their various state boards:

State	Name	Position on Board
California	L. M. K. Boelter	Member
Connecticut	I. L. Newell	Member
Illinois	G. G. Lamb	Chairman
Louisiana	Jesse Coates	Member
Maryland	G. M. Hebbard	Vice-chairman
Massachusetts	E. D. Wilson	Vice-chairman
Missouri	Bruce Williams	Chairman
North Dakota	Alex C. Burr	Chairman
Oregon	S. C. Schwarz	Member
Washington	H. K. Benson	Member
West Virginia	W. W. Hodge	Chairman

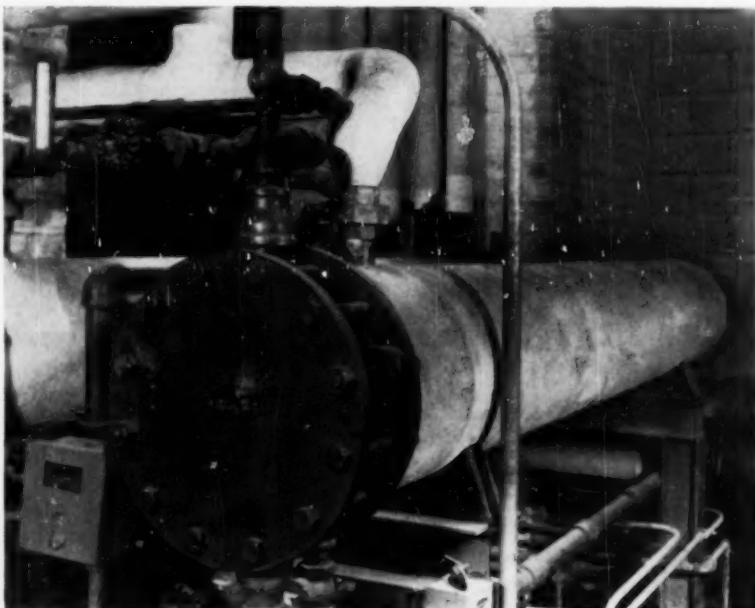
It was then decided that by heavying up some of the diagonal bracing in the vertical bents near the top and introducing temporary diagonal bracing in bays not otherwise braced, the structure would support the derrick without guys and the necessity for long lifts could be avoided.

The additional cost of reinforcing this structure was less than \$1,000, a negligible amount compared with the saving of time and man-hours required to erect a guyed pedestal, the company stated.

## KLOPSTEG ASSOC. DIR. NAT. SCIENCE FOUNDATION

Dr. Paul E. Klopsteg, assistant director of mathematical, physical and engineering sciences of the National Science Foundation, has been appointed to the new position of associate director of the Foundation. Dr. Raymond J. Seeger, program director for physical sciences, has been appointed acting assistant director for mathematical, physical and engineering sciences.

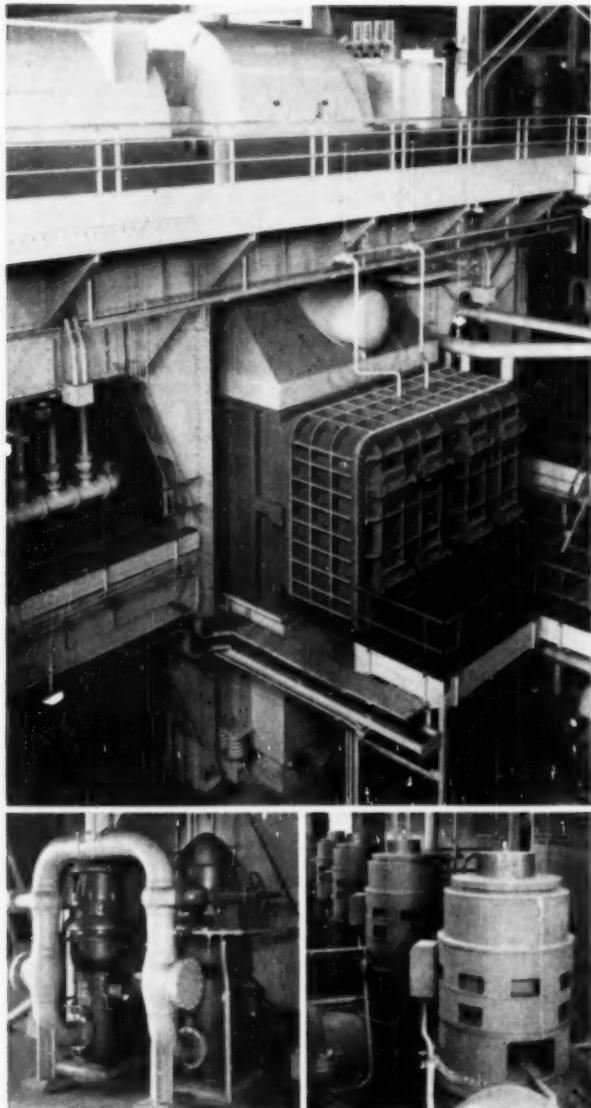
## MOLDED-TYPE PIPE INSULATION



Molded-type pipe insulation has been installed on a 120° F. heat exchanger, by the Union Special Machine Co. Standard 1½-in.-thick molded-type mineral-wool-fiber pipe insulation in two sections was wired in place with 18-gage galvanized iron wire at about 18-in. centers along the 10-in. shell.

Because the standard length of the molded-type pipe sections is 36 in., only three units of insulation were required to cover the 9-ft.-long exchanger. The mineral-fiber insulation was finished with 4-oz. canvas pasted over the surface, sizing and paint. The insulation was cut to fit closely around supports and connecting lines, and the company reports low cost and easy installation.

# Delaware Power & Light installs Two, then orders Third Ingersoll-Rand Condenser at New Edge Moor Power Station



(Top) The 40,000 sq. ft. Ingersoll-Rand surface condenser serving Unit #1. (Left) The two I-R vertical condensate pumps for Unit #1. (Right) The four Ingersoll-Rand circulating-water pumps for both Units #1 and #2.

## ALL THREE UNITS SERVED BY I-R VERTICAL CIRCULATING-WATER AND CONDENSATE PUMPS

The Delaware Power and Light Company's Edge Moor Power Station, on the Delaware River near Wilmington, started furnishing power to the system on June 1, 1951 with two 60/66,000 kw turbine generator units. It will mainly serve the growing business, industry and home load in Wilmington, the surrounding area of Delaware, and the thriving Delmarva Peninsula.

This first major steam plant of the company was engineered and constructed by United Engineers and Constructors, Inc., Philadelphia. Semi-outdoor construction is employed with the economizers, dust collectors, air heaters, flues and stacks located outdoors.

Units One and Two, now on line, are 60/66,000 kw turbine-generators to operate on 1250 psi, 950°F, steam. These two units are served by two Ingersoll-Rand Rectangular Condensers, each containing 40,000 sq. ft. of condensing surface. They are single-pass, vertically divided units with a storage hotwell holding 10,000 gallons of condensate.

Each condenser is served by two Ingersoll-Rand vertical circulating-water pumps, each rated at 36,000 gpm at 25 ft. total head. Also serving each condenser are two I-R vertical condensate pumps, each rated at 1400 gpm at 320 ft. total head.

Within the next few months ground will be broken for a 60,000/75,000 kw turbine-generator addition of reheat design. This new unit, to go on line in late 1954, will also be served by a 40,000 sq. ft. Ingersoll-Rand Rectangular Condenser, I-R circulating-water and condensate pumps. All the Ingersoll-Rand equipment for this third unit essentially duplicates the condensing apparatus for units one and two.

Compact I-R Condensers such as these save valuable space because their rectangular design fits the rectangular space available under the turbine. Installation expense is minimized because I-R condensers are completely assembled at the factory. Then they are disassembled and shipped in large sections, which are completely flanged for easy erection without any field-fitting or strength-welding.

COMPRESSORS • AIR TOOLS • ROCK DRILLS • TURBO-BLOWERS  
CONDENSERS • CENTRIFUGAL PUMPS • DIESEL & GAS ENGINES

# Ingersoll-Rand

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You're looking at a polished section cut from a Duraspun Centrifugal Casting...a casting with 12-14% chromium. It tells better than words of the high quality of Duraspun Centrifugal Castings.

You get a fine, dense, uniform grain structure. Possible air pockets and blow holes are eliminated. Tensile strength is higher than with static castings.

Order Duraspun if you need pipe or tubing. Sizes run up to 15 feet in length; up to 32 inches OD; and down to  $\frac{1}{4}$  inch wall thickness. Odd shaped pieces can be produced providing a circular hole passes uniformly down the center. These, of course, require specially designed casting forms.

If, before ordering or asking us to quote, you would like to know more about our work and facilities, send for our Catalog 3150.

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## ENGINEERING WHO'S WHO TO BE REVISED

The seventh edition of Who's Who in Engineering, the first revision since 1948, is now being compiled under new provisions established by the publisher with the cooperation of an advisory committee of the Engineers Joint Council. The minimum qualifications for inclusion in the volume as revised require that engineers listed be:

Engineers of at least ten years' active practice, at least five of which have been in responsible charge of important engineering work.

Teachers of engineering subjects in colleges or schools of accepted standing who have taught such subjects for at least ten years, at least five of which have been in responsible charge of a major engineering course.

The method of revision to be followed includes resubmission of their material to all who appeared in the sixth edition; invitations to supply data to a large list of engineers who have been variously recommended for inclusion in the past four years; and invitations to other engineers not now included whose activities warrant their appearance in the book.

The A.I.Ch.E. representative to the advisory committee of E.J.C. on the publication is Stephan L. Tyler, Secretary.

## SOAP INDUSTRY TO CONVENE

The soap industry will hold its twenty-sixth annual convention at the Waldorf-Astoria in New York on January 27 to 29 under the auspices of the Association of American Soap & Glycerine Producers, Inc.

Changes resulting from new governmental policies, from new consumer buying trends, and from advances in technology for soap, synthetic detergents, glycerine, and fatty acids will be considered. Among the general speakers will be Carlos P. Romulo, Philippine delegate to the United Nations; Kevin McCann, former assistant to General Eisenhower; and Senator Paul H. Douglas.

## Canadian Student Engineers

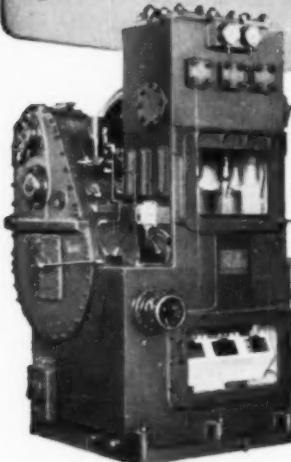
(Continued from page 43)

taking first-year engineering than were registered two years ago.

For the first time in some years the total enrollment of engineering students in all years is up from the previous year by a small margin. The total registration is 8230. The number in the graduating classes, however, is lower than a year ago, amounting to 1357, a reduction of 20% from 1951-52. A still further reduction is forecast for the 1954 graduating class, but in 1955 a small increase may be expected.

(More News on page 48)

# There's an ALDRICH Pump to meet your chemical pumping need...



Aldrich-Groff "POWR-SAVR"  
Controllable Capacity Pump.

## APPLICATIONS

Among many liquids handled by Aldrich Pumps are: caustic solutions, fatty acids, nitric acid, acetic acid, aqua ammonia, anhydrous ammonia, as well as liquids encountered in the petroleum refining, petroleum chemical, and other industries.



## For automatically controlled delivery

This calls for an *Aldrich-Groff "POWR-SAVR"*—a variable stroke triplex pump which controls delivery from 0 to 100% capacity at constant pump and motor speed. Control can be accomplished from any remote point, manually or automatically. Power consumption is almost directly proportional to demand. Units handle any free-flowing liquid at discharge pressures from 300 to 15,000 psi and are available in six sizes: from 2" to 6" stroke and from 5 to 125 bhp. Request Data Sheet 65.

## For high pressure at small volume

Specify the *Aldrich-Lytle Hydro-Pneumatic Unit*. This pump is self-contained, uses normal plant air supply as the power medium, and provides high pressures (up to 20,000 psi) at small volume. Request Data Sheet 69A.

## For medium to high pressure service

Here, several types of constant stroke pumps are available—depending upon the service involved. You may need the Inverted Vertical Triplex (Data Sheet 66), the Vertical Triplex (Data Sheet 26), or the Direct Flow Triplex or Multiplex Pump (Data Sheets 64, 64B).

From our experience in building pumps for the chemical industry, we can—from our engineering and service files—frequently make specific recommendations to meet your chemical pumping needs . . . whether your problem involves corrosion, high viscosity or high pressure.

Any or all of the above Data Sheets are available on request.

**Aldrich Accumulators** are also available to meet your displacement requirements. For information on hydro-pneumatic and weight-loaded types, request Data Sheets 29, 29A.



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# Niagara's HYGROL DRIES AIR BEST

## with exact moisture content

- to control your product's quality
- to prevent condensation on your product or material
- to prevent changes due to moist air in contact with your product
- to protect your material from dampness
- to protect your processing of moisture-sensitive material
- to DRY your material or product
- to pack or store your product safe from moisture damage
- to get exact moisture control for the precise atmosphere condition you need
- to provide precise atmospheric conditions for testing
- to increase your air conditioning capacity
- to DRY large quantities of fresh air from outdoors

### The Niagara's Controlled Humidity Method using HYGROL moisture-absorbent liquid is

**Best and most effective because . . .** it removes moisture as a separate function from cooling or heating and so gives a precise result constantly and always. Niagara machines using liquid contact means of drying air have given over 20 years of service.

**Most reliable because . . .** the absorbent is continuously reconcentrated automatically. No moisture-sensitive instruments are required to control your conditions.

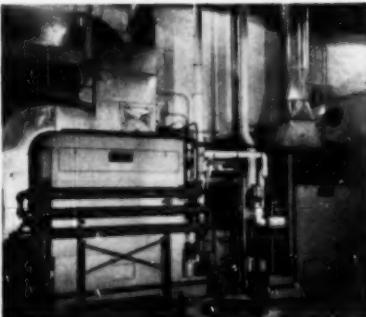
**Most flexible because . . .** you can obtain any condition at will and hold it as long as you wish in either continuous production, testing or storage.

**Easiest to take care of because . . .** the apparatus is simple, parts are accessible, controls are trustworthy.

**Most compact,** taking less space for installation.

**Inexpensive to operate because . . .** no re-heat is needed to obtain the relative humidity you wish in normal temperature ranges and frequently no refrigeration is used to remove moisture.

**The cleanest because . . .** no solids, salts or solutions of solids are used and there are no corrosive or reactive substances.



**Niagara Controlled Humidity  
Air Conditioning**

This method removes moisture from air by contact with a liquid in a small spray chamber. The liquid spray contact temperature and the absorbent concentration, factors that are easily and positively controlled, determine exactly the amount of moisture remaining in the leaving air. Heating or cooling is done as a separate function.

**For complete information write**

**NIAGARA BLOWER COMPANY**

**Dept. EP, 405 Lexington Ave., New York 17, N.Y.**

**District Engineers in Principal Cities of United States and Canada**

### ANOTHER ROLE FOR COAL

The world's power requirements may some day be met entirely with atomic energy, Dr. George Curme, Jr., vice-president of Union Carbide and Carbon Corp., said recently. Coal and petroleum, he predicted, may become sources chiefly of industrial products.

"We are living today," Dr. Curme continued, "in the midst of the greatest revolution civilization has ever known . . . the profound and progressive change in our ways of securing the basic needs of our people, the marked improvement in the standards of living of whole nations, an increasing control of our physical environment." Crop lands that now supply industrial materials such as fibers, coatings, and forest products may be needed to provide food for the world's growing population. To replace this source of raw materials, according to Dr. Curme, the chemical industry will be called upon to supply materials by synthetic methods. Our vast coal reserves, instead of being used for fuel, will meet these new needs.

Dr. Curme spoke at a dinner of the American Chemical Society Pittsburgh Section, where Dr. Homer H. Lowry, director of the Coal Research Laboratory of the Carnegie Institute of Technology, received the Pittsburgh Award for "outstanding service to chemistry and to the community."

### YEAR-END STATEMENTS PREDICT BRIGHT FUTURE

Expansion is the keynote for 1953, according to leaders in the chemical industry. The note of optimism was sounded in year-end statements by various company heads despite acknowledged shortages and some cutbacks in defense spending.

"For those who believe America's postwar expansion is done climbing the hill and is ready to turn down to a lower plateau, the chemical industry may well have some surprises," predicted Charles S. Munson, president, Manufacturing Chemists' Association, Inc., in discussing chemical research and development in 1953. "Rubber can look forward to another record year in 1953," said H. D. Humphreys, Jr., president, United States Rubber Company, and he added that "chemicals and plastics are becoming increasingly important to the rubber industry . . ."

Increasing uses discovered for aluminum in 1952 promise continued growth of the industry in 1953, according to L. W. Wilson, president, Alumunum Company of America. He mentioned among ALCOA's projects a chemical-products plant at Bauxite, Ark.

In the industrial engineering and construction field, William Collins, president, Walter Kidde Constructors, Inc., sees a steady demand being maintained.

## ENGINEERING DEANS TO WORK IN INDUSTRY

Two deans of engineering, both chemical engineers, have joined Du Pont Co.'s engineering department for a "year in industry." Dr. Stephen Crawford, dean of engineering and director of the engineering experiment station at the University of Rhode Island, and Dr. Jesse W. Mason, dean of engineering at Georgia Institute of Technology, are on a year's leave of absence from their college posts to participate in an industrial schedule that will take them through the company's entire engineering organization. The program was inaugurated in 1951 by Granville M. Read, chief engineer, to "bridge the gap between the campus and industry."

## NEW GERMAN HEATING MONOGRAPH

Investigations of the "Heating Effect of Flowing Superheated and Saturated Steam," carried out by Dr. Georg Winckelsesser at the Technical University in Karlsruhe, Germany, are described in a recent addition to Dechema Monographs, a German chemical engineering series. The main conclusion from the experimental data is that, other factors being equal, the heating effect of superheated steam is superior to that of saturated steam. A number of conclusions are also noted regarding the flow of heat within the water layer on the cooling surface.

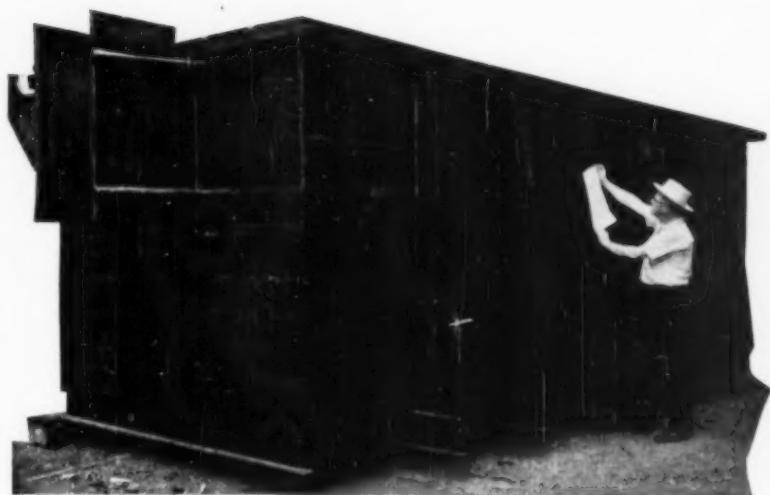
The monograph, No. 244, Vol. 20, may be purchased from Deutsche Gesellschaft für chemisches Apparatewesen, Frankfurt am Main, at a cost of three dollars.

## ADDITION TO SULFATE OF POTASH FACILITIES

International Minerals & Chemical Corp. plans an addition to its sulfate of potash facilities at Carlsbad, N. M. A. Norman Into, vice-president in charge of the potash division, announced that the plant will be in production around the beginning of 1954. The added production resulting from this expansion will amount to approximately 35,000 tons of sulfate of potash a year, he added.

## MARKET RESEARCH LECTURES AT CASE

Chemical market research is the subject of an evening lecture series sponsored by the department of chemistry and chemical engineering of Case Institute of Technology and the Chemical Market Research Association. Beginning on Feb. 3 and continuing weekly through the semester, the program is directed toward people in industrial and academic fields. The series will be given at Case Institute.



# There is a PYROFLEX CONSTRUCTED TANK for EVERY CORROSIVE SOLUTION



Two courses of acid proof brick set in Knight acid proof cement are installed over Pyroflex lining in pickling tank.

Every Pyroflex-Constructed Tank is individually engineered to do a specific job. For example, the pickling tank above must handle a hot sulphuric acid solution. A steel shell was lined with a heat-bonded Pyroflex sheet membrane. Two courses of acid-proof brick set in Knight No. 2 Acid-Proof Cement were installed. Exterior surfaces were covered with Pyroflex. The result is a tank completely resistant inside and out to the corrosive conditions under which it must function.

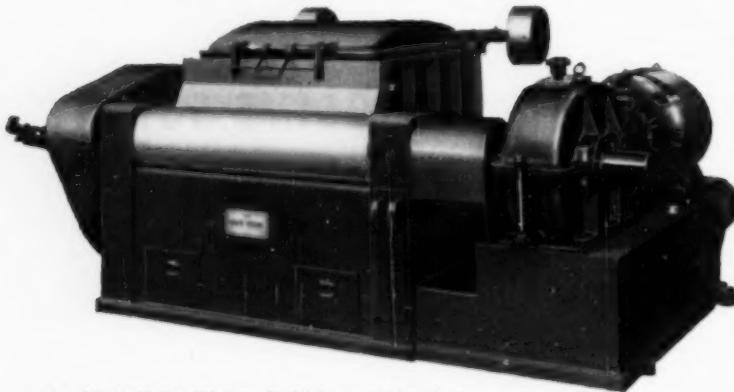
Tanks for pickling stainless must handle nitric and hydrofluoric acid. Suitably constructed tanks are also built for this service. Pyroflex Construction is not limited to the use of any particular materials. Each unit is constructed of whatever materials best meet individual requirements. Thus, you are assured of a tank tailor made to fit your job — to give long trouble-free service with less maintenance and down time. Pyroflex-Constructed Tanks can be shipped F.O.B. Akron, or lined on the job site by skilled field crews.

Write for Bulletin No. 2F, Pyroflex Construction.

**Maurice A. Knight** 701 Kelly Ave., Akron, Ohio  
**Acid and Alkali-proof Chemical Equipment**

# BAKER PERKINS mixers will thoroughly mix and knead almost any material for the chemical processing industry

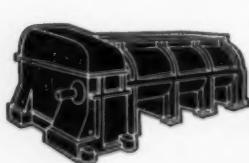
There is a BAKER PERKINS Mixer built to efficiently mix and knead materials ranging in consistency from dry powders and light fluids to stiff plastic masses. Close clearance between the blades and trough keeps every particle of the material in constant motion so that no part of the batch escapes the thorough mixing action of the blades. Intensive kneading is maintained as the material is pulled and squeezed against the blades, saddle and sidewalls. Consult a B-P sales engineer for full facts.



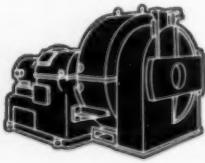
**Size 16, NEM B-P "Universal" Mixing and Kneading Machine** for heavy plastic masses. Working capacity 150 gallons; total capacity 225 gallons. Fabricated steel trough shell jacketed for 150 psi. steam or water pressure. Cast iron trough ends are not jacketed. Saddle section has thermocouple for temperature control. Cast steel Sigma or Double Nabon blades cored for circulating steam or water. Oil tight gear guards; anti-friction bearings. 50 HP motor.

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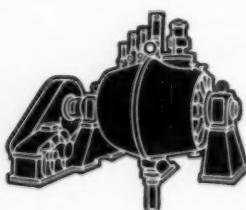
## Other BAKER PERKINS products



EQUIPMENT FOR FOUNDRY INDUSTRY



CENTRIFUGALS



EQUIPMENT FOR RAYON PRODUCTION

## BAKER PERKINS INC.

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

## HIGH FREQUENCY EXTRACTS FATS

A new process for the cold extraction of fats and oils from cellular material, is announced by The Sharples Corp., Philadelphia, who has contracted with British Glues & Chemicals, Ltd., London, England, to handle the process in North America.

This process, which bears the name of I. H. Chayen, technical director and assistant managing director of the British company, is based on the principle of impulse-rendering. The material to be rendered is suspended in a continuous stream of cold water, and passes through a vessel in which the water is subjected to a series of high-speed, high-frequency mechanical impulses. Under these conditions, the water acts on the fat cells like a battery of hydraulic drills; the cells are instantaneously ruptured and the fat is released without the degradation normally resulting from heat or chemical extraction.

Although impulse-rendering is now being used commercially for the continuous cold degreasing of bone, test runs in England and at Sharples, according to the companies, indicate successful application of the principle in a much wider range of fat and oil-bearing animal, fish and vegetable materials.

The first plant employing the Chayen process in North America is at W. Harris, Ltd., well-known bone renderers and glue makers in Toronto, Canada.

In the Harris plant, and three plants of British Glues in England, the broken bones are fed in a continuous stream of cold water, through the impulse-renderer at the rate of 5,000 lb. an hour.

The extraction of fat from the bone takes less than a second, and the fat comes out a white, bland solid of high purity. The fat and degreased bone are then separated by gravity and go by different routes through a series of washing and centrifugal separating processes. The fat goes into storage ready for sale three minutes after the bone is fed into the bone breaker. The degreased bone is ready for glue-making or drying within eight minutes of the start of operations.

The Sharples Corp. has an engineering team working on the process in Phila.

## INDUSTRIAL INSTRUMENTATION AT FLORIDA UNIV.

The University of Florida has announced the fourth annual short course in industrial instrumentation to be held in Gainesville, Fla., Feb. 2-4, under the sponsorship of the College of Engineering. Dr. J. Hillis Miller, president of the University, will open the conference. Prof. R. C. Specht is the conference supervisor.

(More News on page 58)

## LOCAL SECTION

### EDITOR'S NOTE

The past several weeks of 1952 saw considerable activity in the local sections of A.I.Ch.E. throughout the country. Socials, dinner meetings, business meetings, and plant visits were well attended and the discourses, formal and informal, highlighted many current and recurrent problems in the diversified fields of chemical engineering. A vote of thanks goes to all reporters—some nameless here—who covered the events so faithfully and ably. However, we begin on this page a recapitulation of the events and activities, reports of which arrived in this office late in 1952. If your section is not represented here let us have news from you by Jan. 20 and it will be included in the February issue of "C.E.P." in which issue the names of the new section officers will be listed.

Taking a backward glance, and flitting about on unscheduled trips to the local sections:

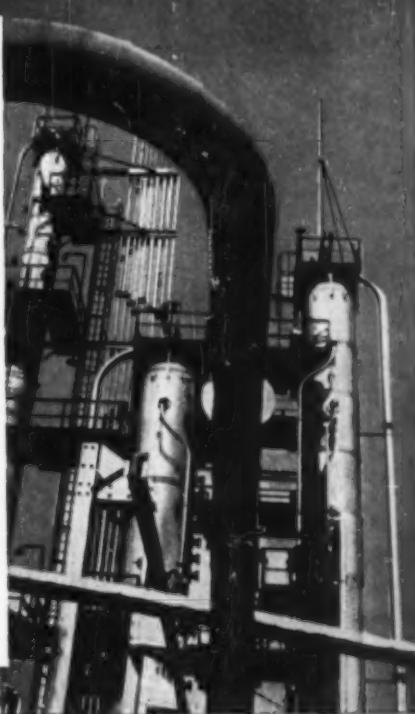
Here is Richard Donovick, of the Squibb Institute for Medical Research, speaking before the New Jersey Section on "Microbial Fermentations, The Crossroads of the Sciences." **Lyle J. Heney** reports that the talk aroused considerable interest. At a prior meeting section members heard Prof. John Tukey, of the mathematics department of Princeton University, talk on "Statistical Design of Experiments."

On Dec. 6 eighty-eight engineers were counted at the gate of the Buffalo refinery of the Socony-Vacuum Oil Co. for the Western New York Section's first plant trip of the year. **J. W. Casten**, reporting on the fine attendance especially for a Saturday morning, congratulated Prentiss Reeves, process engineer of the refinery and organizer of the trip, for his preliminary remarks which included an outline of the general practices of petroleum refinery and gasoline production together with the dewaxing and disposal of end products. Guides took groups through the dewaxing plant, and the thermofoor catalytic cracking unit.

On Dec. 9, thirty members of the Northeastern New York Section in Schenectady heard Robert P. Haviland, of the General Electric project Hermes, give a "Report of the Bumper (two-stage rockets) Program." **Roger E. Larson**, telling about the meeting, said that slides and movies clarified some of the problems of designing, developing, and testing two-stage rockets. At a previous meeting Harold Simon of General Aniline Works, Rensselaer, N. Y., discussed color dyeing explaining how the various types of dyes were affixed to cloth.

Down in the Southwest **W. R. Trutna**, secretary of the South Texas Section, re-

# YOU CAN STOP liquid carry-over in processing vessels WITH **METEX** MIST ELIMINATORS



The unusually high efficiency with which these *knitted* wire mesh units remove the liquid entrainment that occurs in a wide variety of refining and processing operations has enabled engineers to:

1. Improve product quality and eliminate reruns.
2. Prevent contamination in subsequent operations.
3. Recover valuable products previously lost.
4. Operate existing equipment at higher capacities.
5. Design new equipment with smaller dimensions.
6. Achieve more economical processing of lower grade materials.
7. Secure longer "on-stream" periods by removing corrosive liquids.
8. Prevent air pollution by objectionable liquids.

**METEX** Mist Eliminators can be used wherever the problem of liquid entrainment exists. By effecting complete removal of liquids, Mist Eliminators contribute to more efficient and economical processing in such vessels as:

VACUUM PIPE STILLS  
FRACTIONATING TOWERS  
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EVAPORATORS  
ABSORBERS  
SCRUBBERS

COMPRESSORS  
SEPARATORS  
STEAM DRUMS

#### Get the full facts on **METEX** Mist Eliminators

Write for bulletins giving detailed information—including limiting velocities, pressure drop, efficiencies, etc.



## METAL TEXTILE CORPORATION

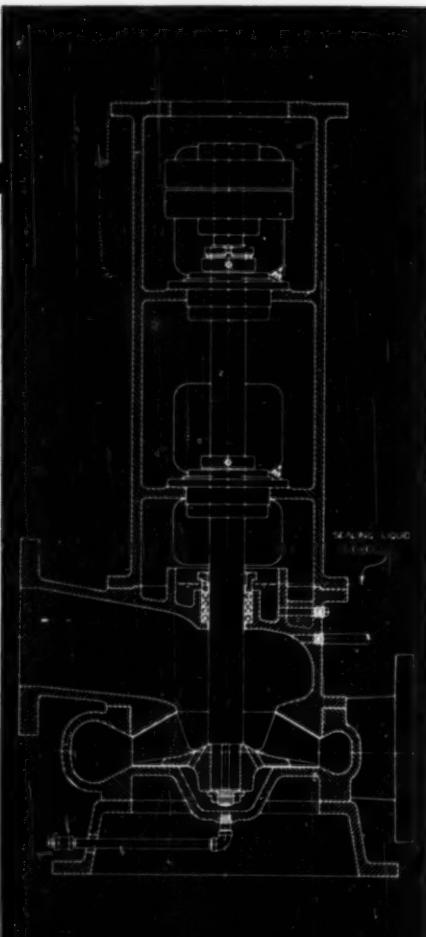
KNITTERS OF WIRE MESH FOR MORE THAN A QUARTER CENTURY



Main Office & Plant, Roselle, N. J. Canadian Plant, Hamilton, Ont.

Right: Cross-section of Lawrence Vertical Top Suction Pump for pumping volatile liquids.

Below: Vertical Top Suction Pump.



## Pump VOLATILE LIQUIDS

- Under a Low Net Positive Suction Head (NSPH)
- Under a High Vacuum
- Without Air or Vapor Binding

When handling volatile liquids under a very low Net Positive Suction Head—from evaporators, for example—a horizontal pump is apt to become vapor-bound. Air or vapor binding is impossible if you install the Lawrence Vertical Top Suction Pump illustrated above. Extremely high vacuums are maintained by filling the space around the packing box with water or some other sealing liquid. The costly delays and shutdowns resulting from vapor binding and loss of vacuum are completely eliminated.

Lawrence Vertical Top Suction Pumps can be furnished in special resistant metals and alloys to handle the most corrosive and abrasive acids and chemicals.

Send for Bulletin 203-4 for complete summary of acid and chemical pump data.



**LAWRENCE**  
MACHINE & PUMP CORPORATION

375 MARKET STREET, LAWRENCE, MASS.



ported that John J. McKetta, Jr., editorial director of Petroleum Refinery, won the Technical Paper Award which was presented at a dinner following the Seventh Annual Technical Session at the Rice Hotel in Houston. The paper titled "Vapor Liquid Equilibrium Constants in the Methane-Water and Ethane-Water Systems," was coauthored by O. L. Culberson of Gulf Research and Development Co., Hammarsville, Pa., who did the work while a student of Dr. McKetta's at the University of Texas.

N. W. Morley has sent word that a dinner meeting of the Ohio Valley Section was held at the Cincinnati Engineering Society headquarters at which William R. Taylor, chemical engineer, Ohio River Valley Water Sanitation Commission, gave an account of the progress being made in cleaning up the Ohio River. A tentative problem on chemical wastes was presented to the audience for solution.

Out in St. Louis on Dec. 16, R. E. Lenz, Monsanto Chemical Co., gave an eager audience his impressions of the Italian chemical industry gathered from a four-month stay in Italy. Andy Pickens reports that Mr. Lenz helped with the start-up of a new chemical plant near Venice. In his talk Mr. Lenz made general observations on the chemical industry including some personal experiences while working in plants with Italian engineers and workmen. At a previous meeting of the St. Louis Section, H. H. Storch, associated with the U. S. Bureau of Mines, discussed the potential industrial importance of synthetic liquid fuel processes of both fuel and chemicals in a talk titled "Catalytic Aspects of Synthetic Fuels Processes." Emphasis was given to the first hydrogenation reaction which turns solid coal into liquid, hydrosplitting and isomerization for the second stage of coal hydrogenation, the Fischer-Tropsch synthesis and the Oxo synthesis.

In Chicago the December meeting was held at the Builders' Club. Neil Blair,



J. J. McKetta, Jr., South Texas technical paper award winner.

assistant chief engineer of Panellit, Inc., discussed centralized instrumentation in the process industries with emphasis on the use of graphic instrument panels. At Hammond, Ind., the previous month, A. M. Holzberg reported more than 100 people heard Capt. E. S. Pettyjohn (U.S.N.R.), Institute of Gas Technology, provide an extensive survey of gasification and synthesis-gas production processes including all pertinent developments both in the U. S. and in Germany. He was followed by George von Fredendorff who described the technical features of the pilot plants built by the Institute of Gas Technology. At a previous meeting Harry McCormack, technical editor of Chemical Processing spoke on "Chemical Engineering—Yesterday, Today, and Tomorrow."

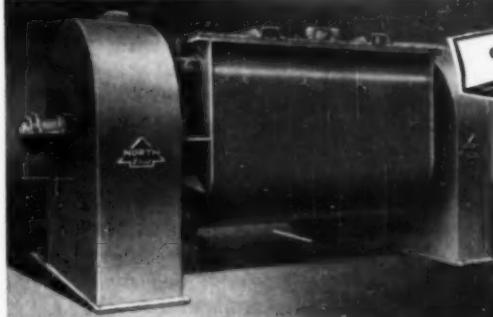
In West Virginia before the Charleston Section, many matters were reported and discussed at meetings held in the latter months of 1952. An announcement was made that an Engineers' Week was being planned for February, 1953. One of the speakers was Harold Hoppens, director of technical service for the Plaskon division of Libbey-Owens-Ford Glass Co., Toledo, Ohio, whose talk "Fiberglas Laminated Polyester Resins" covered, according to A. G. Draeger, the economics, manufacture and applications of this recent development in the plastics field. Mr. Hoppens said that the stimulus for the development of this product was given by the need for satisfactory housing materials for armed services electronics equipment. Further he remarked that the principal application of interest to the chemical industry is that of pipe in 4- to 10-in. diam. Petroleum companies are testing this product on a purely experimental basis. He concluded with the statement that the leaders in the field are looking forward to extending the use of laminated polyester resins to the equivalent of 50 per cent of the present steel applications. At another meeting Stanley C. Orr, assistant factory manager of the Elyria, Ohio, plant of the Pfaudler Co., informed his listeners on the effect of the major alloying agents on the characteristics of stainless steels.

Good news from Roland Vorhees of the Charleston Section is the announcement of the presentation of a course in Rapid Reading which will begin Jan. 28, 1953. The course, under the chairmanship of W. R. Manning of Carbide and Carbon Chemicals Co., will be conducted by Prof. G. F. Needham, associate in charge of the Reading Laboratory, Carnegie Institute of Technology. It will consist of six sessions on alternate Wednesday nights, in the main building of Morris Harvey College, and the fee will be \$7.00 for members of the section and \$8.50 for nonmembers. The section

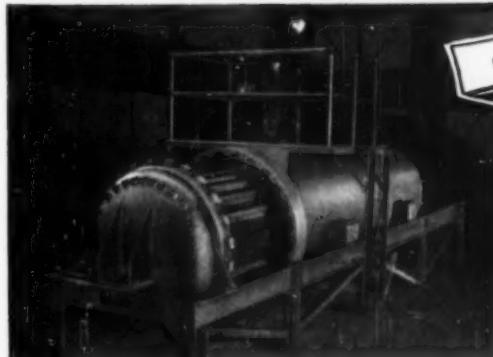
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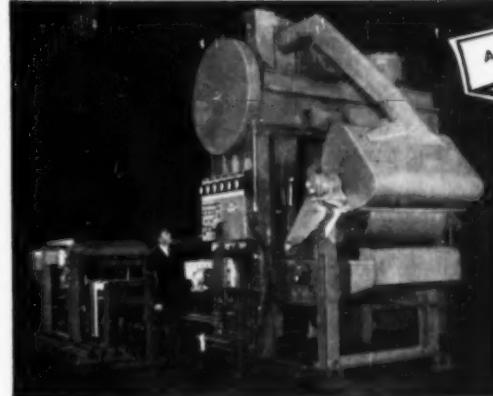
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has just concluded a course in chemical Economics and Finance.

The Central Virginia Section heard Neil Helmess of the engineering service department of Du Pont talk on air pollution. **L. E. Poese**, commenting on the address, said Mr. Helmess estimated that industry is spending annually \$120,000,-000 to correct this problem.

A feature of the December meeting of the Louisville, Ky., Section was a plant trip to the Louisville Refining Co. The new catalytic cracking unit and the graphic instrument panel proved to be of particular interest to the members.

Up in Rochester, N. Y., S. A. Laurich, assistant manager of the crystallizer department of Struthers Wells, gave an address on "Crystallization and Crystallization Equipment" in which he traced the development of equipment for batch and continuous operation. **J. M. Lind-sley** who covered the meeting, stated that the speaker covered a lot of ground as he touched on the many factors that affect the production of desired crystals.

At the Lee Circle Building Auditorium in New Orleans, La., the members of that section, on Dec. 2, listened to Leslie G. Joyner, director, research laboratory, Godchaux Sugars, Inc., cover the general theory of adsorption in an address titled "Not So Solid Solids."

Out in Oklahoma at the College High Cafeteria in Bartlesville, E. A. Sanford, director of research, Pfaudler Co., gave a talk at the December meeting on glass-lined steel and alloy equipment for process industries.

Returning to the South again, J. O. Boesinger discussed the paper industry of the South and its future before the Nashville Section in the New Engineering Building on Vanderbilt Avenue, Dec. 17. His address included some facts on the semichemical pulping process. Mr. Boesinger is head of the Tennessee Chemical Warfare Dept. and division manager of the Mead Paper Corp.

In Kansas City, Mo., the December meeting was on the social side with a "ring out the old—bring in the new" spirit. At a previous meeting, according to the report of **B. E. Olson**, members heard T. L. Gore, Standard Oil Co., discuss the behavior of natural gases at low temperatures.

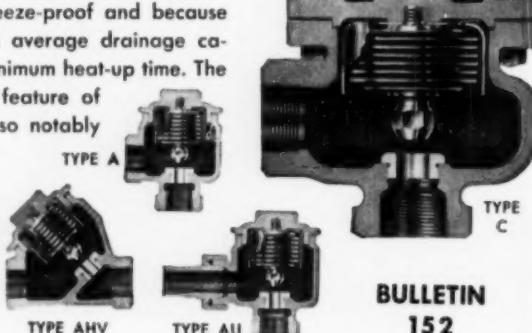
Wending our way westward—**G. S. Peterson**, corresponding secretary of the Southern California Section, informs us that sixty-nine members and guests were present at the meeting at which Thomas E. Myers of the North American Aviation Co. discussed the role of the chemical engineer in rocket propulsion research and described the V-2 rocket motor. Then Reporter Peterson added another note to his story, namely, that the Jan. 20, 1953, meeting will feature a new locale—the Mona Lisa

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BULLETIN

152

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Restaurant in Los Angeles, where J. L. Greenstein, head of the department of astronomy, California Institute of Technology, will speak on "Current Highlights in the Work and Discoveries of Astro-Physicists." He is a member of the staff at Mount Wilson and Palomar Observatories. He plans to discuss methods used and results obtained, according to **S. G. Sevoulian**, in determining presence of various elements and chemical compounds in the atmosphere of the stars.

And in San Francisco at a meeting late in 1952, sixty-five members and guests listened to a discussion on the problems of penicillin production by T. R. Sandberg, director of manufacturing for Cutter Labs. **D. F. Rynning** reports also that, at a later meeting, K. S. Pitzer, dean of College of Chemistry, University of California, covered the over-all possibilities of nuclear power.

In Detroit an end-of-the-year meeting featured a talk by C. W. Phillips, metallurgical engineering department, University of Michigan, on titanium. According to **T. J. Carron**, reporter of the section, the purpose of the talk was to clear up certain misconceptions caused by recent publicity on that metal.

And now after these many stopovers

we are back in New York reminding our readers that F. M. Pyzel, Foster Wheeler Co., will address the New York Section Jan. 21, 1953, at the Brass Rail Restaurant. **Richard F. Shaffer**, publicity chairman of the section, tells us that Mr. Pyzel will talk on ammonia synthesis, tracing its development from research to the first commercial plant of I. G. Farben and will cover the growth of other processes and the differences existing between them.

Before this section on Dec. 16 E. O. Rhodes, technical adviser to the tar products division of the Koppers Co., spoke on the coal tar industry.

His talk, according to **B. H. Rosen**, pointed out that the coal tar industry historically started in Britain in 1782.

The American coal-tar industry started in Baltimore, Md., although the first coal tar was distilled in Buffalo in 1857.

Currently, the coal-tar industry has developed to the point where 750 million gallons of tar are processed a year.

#### Postscript

Many more items have been received since the closing date for this issue which necessarily was advanced because of the Christmas holidays. You'll be seeing your stories next month.—H.R.G.



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## FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

*Chairman of the A.I.Ch.E. Program Committee*

Loren P. Scoville, Jefferson Chemical Co., 260 Madison Ave., New York 16, N. Y.

### MEETINGS

Biloxi, Miss., Buena Vista Hotel, Mar. 8-11, 1953.

**Technical Program Chairman:** Norman A. Spector, Vitro Corp., 233 Broadway, New York 7, N. Y.  
Toronto, Canada, Royal-York Hotel, April 26-29, 1953.

**Technical Program Chairman:** Brymer Williams, Dept. of Chem. and Met. Eng., University of Michigan, Ann Arbor, Mich.

San Francisco, Calif., Fairmont and Mark Hopkins Hotels, Sept. 13-16, 1953.

**Technical Program Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

Annual—St. Louis, Mo., Hotel Jefferson, Dec. 13-16, 1953.

**Technical Program Chairman:** R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

Ann Arbor, Mich., Univ. of Mich., Ann Arbor, Mich., June, 1954—Conference on Nuclear Engineering.

**Technical Program Chairman:** D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

### SYMPOSIA

**Chemical Engineering in Hydro-metallurgy**

**Chairman:** John D. Sullivan, Battelle Memorial Institute, Columbus, Ohio.

**Co-Chairman:** John Clegg, Battelle Memorial Institute, Columbus, Ohio.

**Meeting**—Biloxi, Miss.

### Fluid Mechanics

**Chairman:** R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

**Meeting**—Biloxi, Miss.

**Mineral Engineering Techniques for Chemical Engineers**

**Chairman:** N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

**Co-Chairmen:** T. S. Leary, Calco Chem. Div., Bound Brook, N. J., and D. W. Oakley, Metal & Thermite Corp., Carteret, N. J.

**Meeting**—Biloxi, Miss.

### Ion Exchange and Adsorption

**Chairman:** N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

**Meeting**—San Francisco, Calif.

### Mixing

**Chairman:** J. H. Rushton, Dept. of Chem. Eng., Illinois Inst. of Tech., Chicago, Ill.

**Meeting**—San Francisco, Calif.

### Transport Properties

**Chairman:** J. L. Franklin, Res. Assoc., Humble Oil & Refining Company, Baytown, Texas

**Meeting**—San Francisco, Calif.

### Distillation

**Chairman:** D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

**Meeting**—St. Louis, Mo.

### Dust and Mist Collection

**Chairman:** C. E. Lapple, Dept. of Chem. Eng., Ohio State University, Columbus 10, Ohio.

**Meeting**—St. Louis, Mo.

### Drying

**Chairman:** L. E. Stout, Dept. of Chem. Eng., Washington University, St. Louis 5, Mo.

**Meeting**—St. Louis, Mo.

### Use of Computers in Chemical Engineering

**Chairman:** John R. Bowman, Head, Dept. of Res. in Phys. Chem., Mellon Institute of Industrial Research, Pittsburgh 13, Pa.

**Meeting**—St. Louis, Mo.

### Nuclear Engineering

**Chairman:** D. L. Katz, Chairman Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

**Meeting**—Ann Arbor, Mich.

### Absorption

**Chairman:** R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Loren P. Scoville, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerp, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia, instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 120 days before a meeting cannot be considered.

## Secretary's Report

S. L. TYLER

The Council of the Institute met on Dec. 7 at the Hotel Cleveland, Cleveland, Ohio. This was the meeting at which all committee chairmen were invited to be present and present their reports or discuss any problems with the Council. The following committee chairmen attended and discussed many matters with Council: F. A. Anderson (Chemical Engineering Education Projects Committee); Z. G. Deutsch (Vocational Guidance); J. C. Elgin (Constitution and By-Laws); C. E. Ford (Local Sections); G. F. Jenkins (Public Relations); H. G. Donnelly (Professional Guidance); O. A. Hougen (Awards); D. L. Katz (Nuclear Energy); L. C. Kemp (Admissions); W. E. Lobo (Program and Research); W. R. Marshall (Equipment Testing Procedures); C. C. Monrad (Student Chapters), and J. L. Olsen (Membership).

The Council recorded in the Minutes its appreciation to the Committee Chairmen and Committee personnel for their contributions to the work of the Institute during the year.

The Council received the report of the Tellers Committee and declared the following elected as officers for 1953:

*President*—William T. Nichols

*Vice-President*—Chalmers G. Kirkbride

*Treasurer*—Carl R. DeLong

*Secretary*—Stephen L. Tyler

and the following:

*Directors* for 1953-1955: William T. Dixon, Eger V. Murphree, George G. Oberfell and Lee Van Horn.

Budgets for 1953 for both the Institute and "C.E.P." were presented, discussed and approved.

Appointments of personnel for the standing committees for the year 1953 were made in accordance with recommendations of committee chairmen who were appointed at the November meeting of the Council. Representatives of the Institute in activities in which there is participation with other groups were also appointed.

The Executive Committee met at the Hotel Cleveland on Dec. 7. The Committee approved the Minutes of the previous meeting on Nov. 14, also bills for the month of November. All those whose names appeared in the November, 1952, issue of "C.E.P." were elected to the grades of membership indicated because of no adverse comments received from the membership. Applicants numbering 150 were elected to Student Membership.

Upon recommendation of the Student Chapters Committee, H. Gudebski was

(Continued on next page)

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appointed to succeed C. G. Duncombe as counselor of the student chapter at the University of Detroit, J. O. Maloney to succeed S. A. Miller and J. S. Smatko to succeed F. J. Lockhart at the University of Southern California.

Resignations of twenty members were accepted.

The name of W. P. Chandler was placed on the Suspense List because of his entering the Armed Forces. Reports had been received at the Secretary's Office that J. H. Barnard, Jr., R. W. Peterson and E. W. Samoden had completed their tour of duty in the Armed Forces and they were therefore returned to participating membership in the Institute.

Five elections to Junior membership were rescinded because of non-acceptance on the part of the applicants.

## FISHER PRESIDENT OF A. C. S., 1954

Harry L. Fisher, well-known authority on the chemistry of rubber, has been elected president of the A. C. S. for 1954. At present special assistant to the director of the Office of Synthetic Rubber, Reconstruction Finance Corporation, Dr. Fisher was director of organic research of U. S. Industrial Chemicals, Inc., New York, until his retirement in 1950. He also has been associated with United States Rubber Co. and B. F. Goodrich Co.

In 1949 Dr. Fisher received the Charles Goodyear Medal of A. C. S. for outstanding achievement in the chemistry of rubber, and he has also received other honors, including the Modern Pioneer Award of the National Association of Manufacturers and the Edgar Marburg Lectureship of the A. S. T. M.

Born in Kingston, N. Y., Dr. Fisher received his bachelor's degree from Williams College and his doctorate from Columbia University in 1912.

## TORONTO SYMPOSIUM ON COMMUNICATIONS

A symposium on communications, featuring a series of papers on writing and speaking for the engineer will be a highlight of the meeting at Toronto of the A.I.Ch.E. and the Chemical Engineering Division of The Chemical Institute of Canada, April 27 to 29, 1953.

The ever-increasing complexity of chemical engineering has focused attention on the need for effective means of transmitting ideas. This symposium, which has been under consideration for some time, will present the most advanced developments on the subject.

Also on the topic of communications will be the luncheon address on April 27 by C. F. Braun of the C. F. Braun Co., Alhambra, Calif.

# PEOPLE

**Charles Allen Thomas**, president of Monsanto Chemical Co. and chairman of the board of directors of the American Chemical Society, has been chosen to receive the highest award in American industrial chemistry, the Perkins Medal of the American Section of the Society of Chemical

Industry, for 1953. The Perkin Medal is bestowed for outstanding achievement in applied chemistry.

Dr. Thomas is honored for outstanding contributions to many phases of industrial chemical development. In 1946 he was one of the five authors of "A Report on the International Control of Atomic Energy" prepared for the Secretary of State's Committee on Atomic Energy.

In 1947 Dr. Thomas was awarded the Industrial Research Institute Medal for outstanding achievement in the administration of industrial research. A year later he was awarded the American Institute of Chemists Gold Medal, and in 1952 he received the fifth Missouri Honor Award for Distinguished Service in Engineering presented by the University of Missouri.

**C. A. Wolbach, Jr.**, has recently joined Singmaster & Breyer, metallurgists and chemical engineers of New York. He has had twelve years of chemical plant experience in engineering and development work with particular specialization in the filtration and dust-collection fields. He received his B.S. in chemical engineering from Lehigh University in 1940 and was associated with the titanium division of the National Lead Co. as research chemist and development engineer until 1951. For two years during the war he was assigned to the Special Engineer Detachment at Oak Ridge. More recently he was sales engineer for the Equipment Development Co. of Montclair, N. J.

## R. NORRIS SHREVE ON IMPORTANT MISSION

R. Norris Shreve, professor of chemical engineering at Purdue University, Lafayette, Ind., has left for Formosa to study engineering education at the request of the Government and Purdue. The University has asked him to head up such an investigation and upon his return to organize a group of its professors to go to Formosa for two years. Chinese instructors will go to Purdue for observation and training.



**Lawrence W. Bass**, industrial research executive, has recently become associated with Arthur D. Little, Inc. where he will be primarily concerned with the increasing client demand on the company staff for consultation on the effective organization and management of research activities.

Prior to his association with Arthur D. Little, Inc. Dr. Bass had most recently been vice-president in charge of research for U. S. Industrial Chemicals Co., where he had responsibility for all research and development work on chemicals, insecticides, and synthetic resins. As director of the New England Industrial Research Foundation Dr. Bass acted in an advisory capacity for numerous companies and trade groups, and from 1944 to 1948 he served as director of chemical research for Air Reduction Co.

## PERSONNEL CHANGES AT CHEROKEE PLANT

New personnel assignments have been made at the Cherokee plant of Merck & Co., Inc. at Danville, Pa. **W. E. Keppler** assumed the position of Cherokee production control manager Jan. 1. This new position will include the supervision of the factory stock and production warehouse. **Frank Skrek** is now technical assistant to the superintendent of manufacturing. **E. R. Boulden** has been appointed head of the factory which is producing a chemical product for government use at Cherokee.

**C. William Hardell**, formerly general superintendent of Sinclair Rubber, Inc., has been appointed vice-president and manager of manufacturing for Sinclair Chemicals, Inc. Both companies are subsidiaries of Sinclair Oil Corp. A graduate of the University of Wisconsin, he joined the Sinclair organization in 1934. He was process superintendent for Sinclair Rubber, Inc., from 1942 to 1948, assistant superintendent of Sinclair's refinery at Wellsville, N. Y., until 1950, when he became general superintendent of Sinclair Rubber, Inc.



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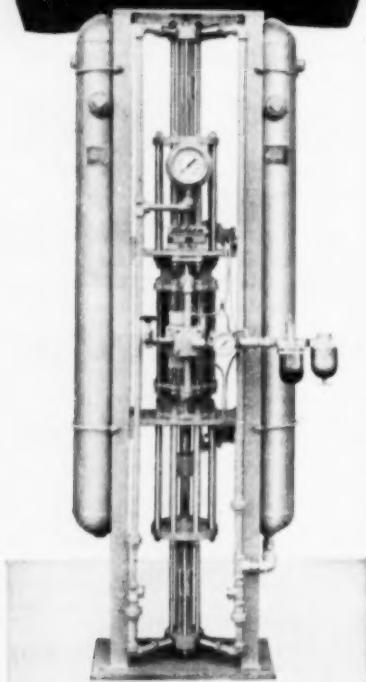
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**Harry W. Haines, Jr.**, has recently joined Vulcan Engineering Division, Vulcan Copper & Supply Co. Mr. Haines, a development engineer with Vulcan, was formerly a Fellow of the Mellon Institute of Industrial Research, Pittsburgh, Pa., holding a multiple fellowship sustained by the Texas Gulf Sulphur Co. Haines is a graduate of the University of Illinois and holds a Master's degree in chemical engineering from the University of Pittsburgh.



**George Armistead, Jr.**, consulting chemical engineer of Washington, has recently been appointed member of the Board of Registration for Professional Engineers.

He has long been associated with developments in oil refining and new chemical projects throughout the United States and Canada. Armistead's appointment by the Commissioners of the District of Columbia is for five years and he will serve as the chemical engineering representative on the Board of Registration, as provided by law. He is head of the consulting firm of George Armistead & Co.

**Donald F. Othmer**, a leading international consultant on chemical industries, who is head of the department of chemical engineering at the Polytechnic Institute of Brooklyn, is now in Burma at the request of the Burmese Government. He is there to take part in the Burma Technical and Economic Survey now in progress in cooperation with the United States Government. This will be Dr. Othmer's third world-circling trip in the last eighteen months to confer with officials and industrialists of many countries on the development of their chemical industries. After his study of Burmese industries, Dr. Othmer will prepare a report complete with recommendations on how methods and techniques can be improved.

**Noel R. Maleady**, General Electric Co., Pittsfield, has been appointed supervisor of materials and processes in the transformer plant being constructed at Rome, Ga. Maleady went to the transformer and allied products laboratory at Pittsfield in 1941. Subsequently he was made supervising engineer of chemical engineering in the process engineering section.

## CATTERSON ADVANCED BY INTERNAT. MINERALS

The appointment of **F. H. Catterson** to the newly created position of assistant general production manager of the Amino products division of International Minerals & Chemical Corp., Chicago, Ill., was recently announced. In this new position, Catterson will be responsible for the general supervision of the acquisition of raw materials and supplies for the division's plant at Rossford, Ohio, for labor relations in both the Rossford and San Jose plants, and for the development of sources of such new raw materials as may be required for the division's operations. Catterson had been resident production manager of the San Jose plant since 1947. He joined the Amino products division in 1945 as project manager during the design and construction of the San Jose plant. He was graduated from the University of Colorado with a B.S. degree in chemical engineering.

## PUBLIC SERVICE AWARD GOES TO C. L. PARSONS

For his many contributions to national welfare and security during his career as chief chemist of the U.S. Bureau of Mines and, from 1907 to 1945, as secretary of the A.C.S., Charles Lathrop Parsons received the A.C.S.'s first award for public service. Two hundred leaders of the chemical profession and industry from all parts of the country paid tribute to Dr. Parsons, now 85, at a dinner in the Hotel Washington, Washington, D. C., on Dec. 8 when the award was presented.

Dr. Parsons' research on the atomic weight of beryllium won for him the William H. Nichols Medal of the A.C.S.'s New York Section in 1905, and in 1932 he received the society's Priestley Medal for his "distinguished service" to the science. After a lengthy period as teacher and professor at the University of New Hampshire, Dr. Parsons went to Washington in 1911 as chief of the Bureau of Mines division of Mineral Technology. He was the bureau's chief chemist from 1916 to 1919.

**Thomas H. Chilton**, 1951 President of A.I.Ch.E. and vice-president of Engineers Joint Council, represented the Council at the ceremony transferring the Declaration of Independence and Constitution to the Archives Building, Washington, D. C., on Dec. 15.



**Max E. Bretschger**, formerly vice-president of Buffalo Electro-Chemical Co., Inc., has been elected president of the company with which he has been affiliated since 1926.

Prior to his joining the Buffalo outfit he was plant manager, Elfa, Elektrochemische Fabrik, Aarau, Switzerland, manufacturers of electrolytic hydrogen peroxide. He began his professional career with L. Chiozza & Co., Cervignano, Austria, in 1910; in 1912 he was with Ehrick & Graetz, Berlin, Germany; and then went to Chemische Fabrik Griesheim-Elektron, Frankfort-on-Main, Germany, in 1915 as a chemist in charge of manufacturing of chlorate of potassium, caustic potash, chlorine, chloride of lime and liquefaction of chlorine. Dr. Bretschger holds a Ph.D. degree from the University of Zurich, Switzerland, and is considered an authority on the electrolytic manufacture of peroxide of hydrogen. **Frederick A. Gilbert**, formerly manager of the company at the Vancouver, Wash., plant, has been elected vice-president. He will make his headquarters in Buffalo.



**Joseph Stewart**, a research chemist in the Esso Laboratories of the Standard Oil Development Co., was guest speaker at a recent meeting of the Philadelphia Section of the American Chemical Society. Mr. Stewart joined the Esso Laboratories in 1945 after attending Long Island University and Purdue University, from which he received his M.S. in organic chemistry.

**Francis W. Winn** has been appointed assistant chief process engineer for the Catalytic Construction Co., Philadelphia, Pa. His duties will encompass the three broad fields of petroleum, atomic energy, and chemical projects. His responsibilities include research and development, process design and

theoretical correlations. Mr. Winn was formerly with the Socony-Vacuum Oil Co. in the research and development department where he specialized for five years on process design and economic studies of refinery equipment, and developed an exact computation procedure for multicomponent fractionation.

(More News About People on page 63)

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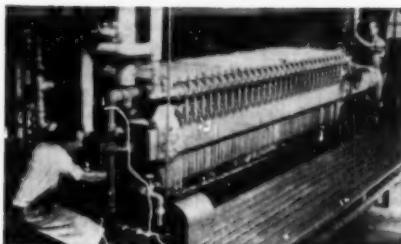
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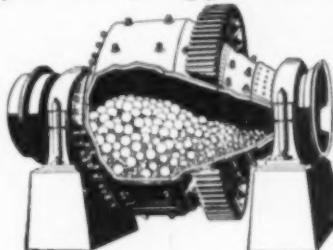
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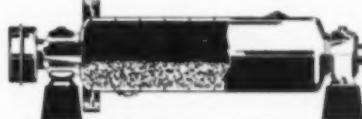
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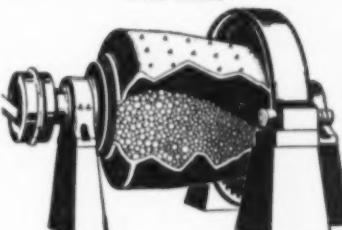
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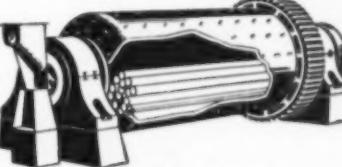
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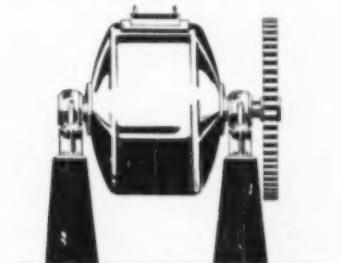
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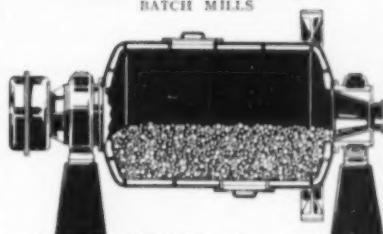
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## SITUATIONS OPEN

**COST ENGINEER**—Chemical or mechanical engineer with two to three years' experience in process engineering and experience or interest in cost estimating to make process and product cost estimates on proposed research projects. Midwest location. Send replies to Box 2-1.

**TECHNICAL LIBRARIAN**—Engineer with library experience or librarian with technical library experience to run established research library responsible for periodicals, books, laboratory notebooks and permanent filing. Midwest location. Send replies to Box 3-1.

### SALES ENGINEER

Wanted by Process Equipment Manufacturer in western New York. Chemical or Mechanical Engineering background necessary. Experience desirable but not required. Opportunity with well established, growing concern. Send résumé to Box 1-1.

### SENIOR CHEMICAL ENGINEER

Experienced graduate chemical engineer required for large research and development organization in Northern Rhodesia. Duties relate to process metallurgy of copper, cobalt, lead, zinc and other base metals. Applicant must have minimum five years' industrial experience. Total remuneration approximately £2,400 per annum comprising basic salary, variable metal bonus, and cost of living allowance. Generous pension and leave privileges. Applications stating age, marital status, qualifications, experience record, availability, and accompanied by a recent photograph should be addressed to: The Secretary, P. O. Box 172, Kitwe, Northern Rhodesia.

### RESEARCH AND DEVELOPMENT

Established medium-size company, one of leaders in its field, has opening for recent or prospective chemical engineering graduate in expanding development program. Location upstate New York. Excellent working conditions. Liberal company benefits. Assistance in obtaining housing. Please give details of education and experience and salary requirements. Box 6-1.

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## SITUATIONS WANTED

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**CHEMICAL ENGINEER**—M.Ch.E. Eight years' experience in process development, trouble shooting, and design and start-up of chemical plants. Publications, patent. Desire position requiring initiative with growing consulting or chemical company. Prefer West Coast or metropolitan area. Box 4-1.

**CHEMICAL ENGINEER**—B.S.Ch.E. 1942. Experience includes process and mechanical design of ammonia synthesis, nitric acid and ammonium nitrate units. Complete project responsibility, expansion planning, estimates and reports. Best references. Box 5-1.

**CHEMICAL ENGINEER**—B.S. Chemical Engineering 1950. Age 26, family. One year graduate work as graduate assistant. Presently serving with Army Chemical Corps as project engineer. Desire position in development or technical service. Box 10-1.

**EXECUTIVE SALESMAN**—Experienced in processes, equipment, and engineering services to chemical, pigment, steel and industrial groups in the East. B.S.Ch.E. 1940. For active creative representation outline your opening in confidence to Box 11-1.

**CHEMICAL ENGINEER**—B.S. 1936. Married, family. Thirteen years pilot plant research and development, industrial fermentations and cost analysis. Good working knowledge of electronics, electricity, and instruments. Present salary \$6500. Box 12-1.

**CHEMICAL ENGINEER**—Ph.D. 1951. Age 27, married, veteran. Experience in technical development and technical administration fields of atomic energy. Extensive knowledge of unit operations (especially diffusional processes), mathematics, and thermodynamics. Desire new and challenging position in research and development or technical administration. Box 13-1.

**CHEMICAL ENGINEER**—34, family, P.E. Six years' experience in development, manufacture, application of electrical insulation. Extensive background resin plant engineering, automatic control applications. Present salary \$9,200. Desire position in New York City area. Box 14-1.

**CHEMICAL ENGINEER BACHELORS**—Four years' experience including some high-pressure synthesis wants production job with possibilities. 27 years old. Junior member A.I.Ch.E. South or Southwest location preferred. Salary secondary if the job's right. Box 15-1.

**B.S.Ch.E.**—1942. 10½ years' petroleum refinery experience: lubricants processing and research; plant operations on alkylation, isomerization, and miscellaneous units. Five years' pilot plant supervision. Married, 31. Will consider sales, technical writing, anything with future based on work output. Box 16-1.

**ENGINEERING MANAGER AVAILABLE**—Chemical engineer with background in complete plant design and preparation and analysis of budgets for existing and proposed industrial installations. Bulk of previous experience in detergent, pharmaceutical, and organic chemicals fields. Metropolitan N. Y. preferred. Box 17-1.

**CHEMICAL ENGINEER**—Ph.D. P.E. under 40. Thirteen years' diversified experience in fine chemicals, pharmaceuticals, plastics, and foods in teaching, productive supervision, research and technical administration. Desire responsible position in Eastern U.S.A. Available immediately. Box 18-1.

**CHEMICAL ENGINEER**—33. B.Ch.E. Ten years' extensive refinery experience in process design and development, operations and economic evaluations with major oil company. Family. Desire position of responsibility with aggressive and expanding company. Box 19-1.

**CHEMICAL ENGINEER**—M.S. 1947. Age 28, married. Five years' experience in petrochemicals and resins including process design, process development, and production. Desire position with future in oil or chemical industry. Present salary \$6500. Box 20-1.

**CHEMICAL ENGINEER**—B.Ch.E. 1950. Two years' experience process development with Army and small production. Presently employed with pharmaceutical research and development laboratory. Wish position in process development. New York City area. Box 21-1.

**CHEMICAL ENGINEER**—M.S. in Ch.E. Well qualified for process engineering or production supervision. Excellent experience in petrochemicals research, production, and process development. Top scholastic record. Ultimate ambition is administration. Box 22-1.

**CHEMICAL ENGINEER**—B.Ch.E. Age 27, single. Six years research, process development, design, pilot plant, pharmaceuticals, lacquers, synthetics, explosives, atomic energy. Excellent background for production, development or sales. Personable, friendly and cooperative. Any location with firm offering genuine opportunity. Box 23-1.

**CHEMICAL ENGINEER**—B.Ch.E. 1944. Family. Nine years' total experience in petroleum economics and process development, and some sales service engineering for chemical equipment manufacturers. Prefer administrative type employment in small company. Box 24-1.

**INDIAN CHEMICAL ENGINEER**—Age 29. Ten years' chemical control, erection experience in oil hydrogenation and allied plants. Desire employment opportunity with American oil processors, to expand knowledge. Please correspond O. P. Narula, Narula Lodge, Modinagar (India).

#### Nonmembers

**CHEMICAL ENGINEER**—B.Ch.E. 1942. Graduate training in thermo, kinetics, and languages. Veteran, 31, family. 7½ years' diversified experience research and development, coal tar, fluidization, extractive metallurgy, foreign consulting and sales. Present salary \$6000. Box 25-1.

**CHEMICAL ENGINEER**—3-time veteran, family, 25. Six months experience as refinery chemist. Desire engineering position eventually leading to design work. Box 26-1.



## PEOPLE

(Continued from page 61)

**Dominic J. Oriolo** has been added to the process engineering staff of the

Catalytic Construction Co., Philadelphia, Pa. His position will be that of project director of one of Catalytic's major operations. Mr. Oriolo went to Catalytic from Rohm & Haas where he spent five years as a plant development engineer dealing with design, operation and technical service of chemical plants.

**R. A. Lindsay** has been appointed heavy industries section manager of technical service and development of The Dow Chemical Co., Midland, Mich. He went to this post from his former position as section head of chemical engineering products, organic chemical sales. Lindsay, who took his M.S. degree in chemical engineering at the University of Michigan in 1940, joined Dow's consulting engineering division in 1941, engaging in process engineering design and operation.

**James R. Britt**, formerly with Arkansas Fuel Oil Co., Shreveport, La., recently joined Delta Engineering Corp., Houston, Tex., to assume management of its construction division. In his new capacity he is responsible for the construction operations of an engineering contractor engaged in petroleum, petrochemicals and natural gas facilities. Mr. Britt entered the oil and gas field as a plant engineer for the Cities Service organization in 1936 after receiving his degree in chemical engineering from Louisiana State University. He remained with the Cities Service group finally serving as superintendent of the natural gasoline division of Arkansas Fuel Oil Co.

**Charles F. Bonilla** has been elected chairman of the Middle Atlantic Section of the American Society for Engineering Education for 1953. Dr. Bonilla has been professor of chemical engineering at Columbia University since 1948. He was previously at The Johns Hopkins University, where he headed the chemical engineering department from 1943 to 1949.

(More News About People, and Necrology on page 64)



**REDUCE INSTALLATION COSTS!** Entire assembly ready to attach to crane or hoist. Only a cable connection is run from Baldwin Load Cell to REMOTE RECORDER.

**REDUCE OPERATING COSTS!** Great savings in time and man power possible because weighing and transporting operations are combined. Easily removed from crane.

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Electrical Capacity—A. C. 115V., 5Amp., 230V., 2Amp., D. C. 115V., 2.5Amp., 230V., 1Amp.

WRITE FOR BULLETIN CA-6DP

THE MERCOID CORPORATION  
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Herschel H. Cudd has been appointed acting director of Georgia Tech's State Engineering Experiment Station. Dr. Cudd, who has served as head of the Station's chemical sciences division since 1950, has a background of industrial research experience, including employment with

Du Pont's rayon technical division, International Minerals and Chemicals Corp., and West Point Manufacturing Co. Prior to joining the Station's staff, Dr. Cudd was director of West Point's Lantuck division. He received his B.S. in chemistry from Texas A. & I. in 1933 and his Ph.D. in physical chemistry from the University of Texas in 1941.

Walter S. Kaghan was appointed a group leader in the research and development department of Olin cellophane division, Olin Industries, Inc. Dr. Kaghan went to Olin from Rose Polytechnic Institute where he was assistant professor of chemical engineering. He is the former director of the Resinous Research Associates. Previously he was a process engineer for the Kellex Corp., a chemical engineer for the electro-chemical department of Du Pont Co., and a research engineer for the St. Regis Paper Co. He received his B.Ch.E. degree at City College of New York, N.Y. from New York University and his Ph.D. in chemical engineering from Purdue University.

Jay B. Mitchelson is now superintendent of chemical operations with the Goodyear Atomic Corp., which will operate the government's Uranium-235 plant, now under construction in southern Ohio. He was formerly assistant manager of Goodyear Tire & Rubber Co.'s chemical engineering division at Akron. A graduate of Otterbein College and Ohio State University, Mitchelson started to work at Goodyear in 1937 and following a training period was assigned to the research laboratories on synthetic rubber. Subsequently he moved into the pilot plant, becoming senior chemical engineer, section head, and assistant manager of the chemical engineering division, the position he held until he was assigned the aforementioned supervisory duty with Goodyear Atomic Corp.



Charles H. Riesz has joined the staff of Armour Research Foundation of Illinois Institute of Technology in Chicago. He is heading project research in the area of catalysis, for industrial applications. Dr. Riesz went to the Foundation from the Institute of Gas Technology, where he had investigated numerous catalysis applications to the utility gas since his appointment in 1941. He was in charge of the laboratory and bench-scale, and later the pilot-plant, development of catalytic gasification of higher hydrocarbons, including the catalytic reforming of natural gas. Previous industrial affiliations were with Universal Oil Products Co., Gulf Research and Development Co., Sinclair Refining Co., and Eastman Kodak Co.

J. M. Geist has been appointed to the department of chemical engineering at the "Technion" Hebrew Institute of Technology, Haifa, Israel. It was previously stated in "C.E.P." that Dr. Geist had been appointed to the department of chemical engineering at the American Technion Society, New York. The American Technion Society serves as the American sponsor for the Institute in Israel.

R. W. Schramm of Spencer Chemical Co. has been transferred to New York as staff specialist in the development department. He is a graduate of the University of Notre Dame in 1944 with a B.S. degree in chemical engineering, and in 1949 received an M.S. degree in business administration at Indiana University. Before attending Indiana, Mr. Schramm worked four years as a chemical engineer with the Carbide and Carbon Chemicals Corp. in Whiting, Ind. He went to the general offices of Spencer in Kansas City in January, 1949, and has been manager of market research for Spencer since April, 1951.

## Necrology

Chemical Engineering Progress has recently received news of the deaths of the following:

J. Strother Miller, consultant, asphalt technology, Rahway, N. J. He was at one time associated with the Barber Co., Inc., Barber, N. J.

William B. Shanley, West Coast representative of Universal Oil Products Co. He was a graduate of Notre Dame and had been with Universal Oil Products for more than twenty-two years.

Robert E. Drummond, engineering supervisor in the central research department of Minnesota Mining & Manufacturing Co. Mr. Drummond was graduated from the University of Minnesota and was employed by the Sherwin-Williams Co. in Chicago from 1946-47.

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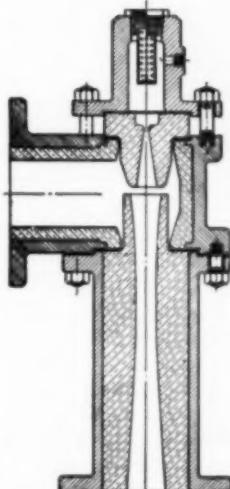
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**"she might**

**have been my kid..."**

**T**here was no time to stop, see? She comes running out from behind this parked car right under my wheels. Her hair is in pig-tails, and with the sun shining on it, she might have been my kid. We got her to the hospital. It took 3 pints of blood to bring her around. All I have to do is remember the sound of those screaming tires—and I know

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Yes, all kinds of people give blood—truck drivers, office workers, salesmen. And—for all kinds of reasons. But whatever *your* reason, this you can be sure of: Whether your blood goes to a local hospital, a combat area or for Civil Defense needs—this priceless, painless gift will some day save an American life!

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- Have you given your employees time off to make blood donations?
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- Have you arranged to have a Bloodmobile make regular visits?
- Has your management endorsed the local Blood Donor Program?
- Have you informed your employees of your company's plan of co-operation?
- Was this information given through Plant Bulletin or House Magazine?
- Have you conducted a Donor Pledge Campaign in your company?
- Have you set up a list of volunteers so that efficient plans can be made for scheduling donors?

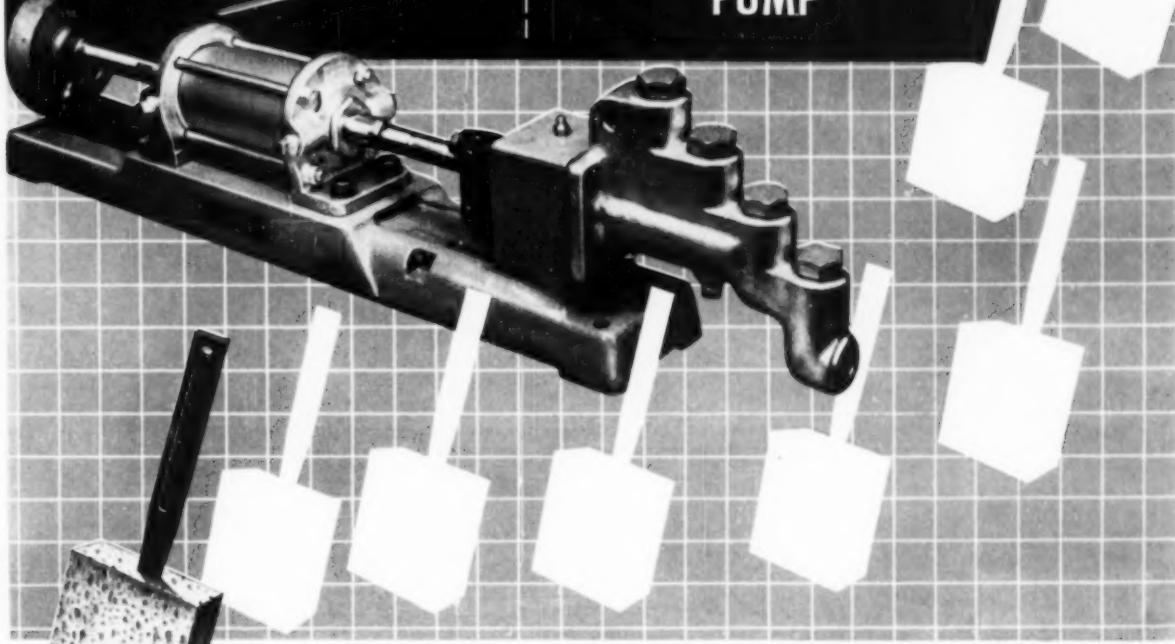
Remember, as long as a *single* pint of blood may mean the difference between life and death for *any* American . . . the need for blood is *urgent*!

**Give Blood Now**  
CALL YOUR RED CROSS TODAY!  
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lulose sponges, when the  
company installed a Milton Roy  
"aiROYmetric" Pump for a key  
production process.

The operation consisted of pumping a measured amount of glue into each sponge so that a plastic handle could be attached. The pumping process replaced manually operated equipment.

With use of the Milton Roy "aiROYmetric" Pump and other associated equipment, O-CEL-O was able to produce in one hour

the number of plastic handle sponges which formerly took eight hours—a production increase of 700%!

The "aiROYmetric" Pump feeds 0.8 gallons of glue per hour at room temperatures against a pressure of 35 pounds per square inch. O-CEL-O's engineers report that the pump has performed dependably since installation, with 75% less maintenance time.

Performance in this operation demonstrates the versatility of Milton Roy Controlled Volume Pumps. Precision metering instruments, they are designed to pump practically any liquid in measured

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It will be worth your while to consider these versatile pumps if your requirements call for precise metering of liquids in controlled volume. For additional information on Milton Roy Air-Powered or Motor-Driven Controlled Volume Pumps, write us. Or call our representative listed in your classified telephone directory.

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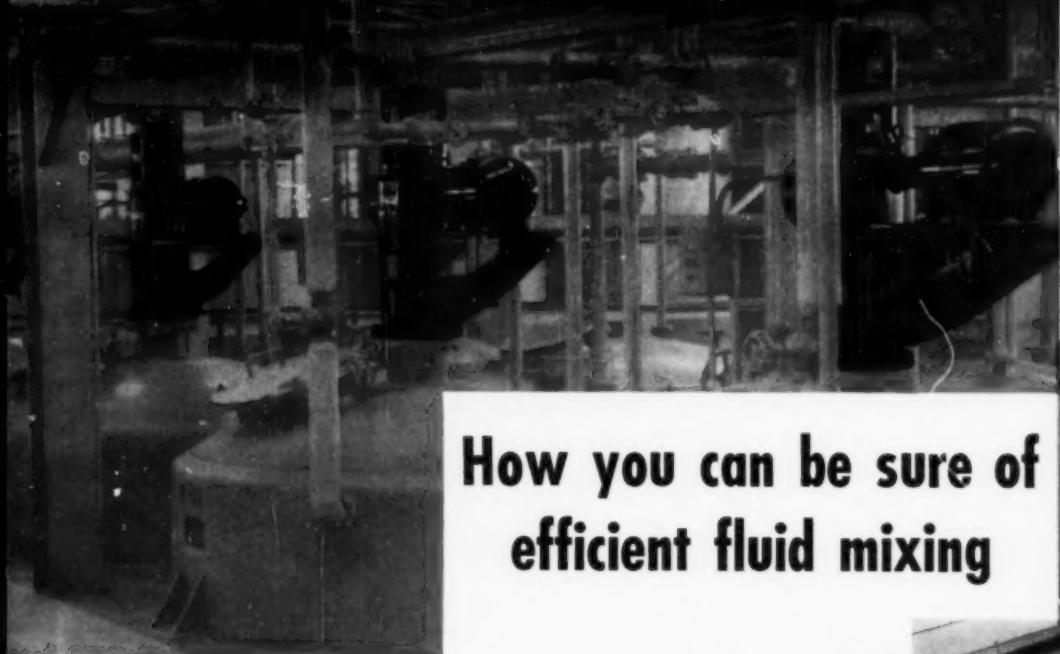


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- |                   |                      |
|-------------------|----------------------|
| heat transfer     | washing              |
| gas dispersion    | dissolving           |
| solids suspension | crystal size control |

All you do is tell us a few facts about the materials, the tank or vessel, the end results you want, and how quickly you want them. We do the rest—and guarantee you'll be satisfied.

This wouldn't be possible without four things:

Really wide experience in serving the process industries

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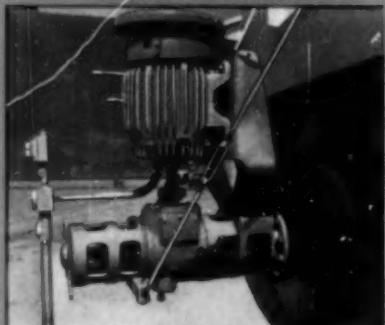
A force of over 125 experienced mixing engineers at the factory and in 26 major industrial sections throughout the country

Fullest selection of *field-proven* equipment to meet every fluid mixing requirement

We think we have all four. We're sure enough to bet on it. When can we get together?



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This library of mixing information is yours for the asking. Catalogs contain helpful data on impeller selection; sizing; best type of vessel; valuable installation and operating hints; complete description of LIGHTNIN Mixers.

**MIXCO** fluid mixing specialists

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- B-104 Side Entering Mixers
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- B-107 Mixing Data Sheet

Please send me the catalogs checked at left.

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